(41)

MOLOKAI WATER SYSTEMS PLAN

PREPARED FOR THE

MAUI COUNTY DEPARTMENT OF WATER SUPPLY

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prepared for the
Maui County Department of Water Supply

by
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TABLE OF CONTENTS

	Page
Summary and Conclusions	1
Introduction	2
Inventory of Existing Water Systems	4
Water Systems Inventoried	5
Maui County Department of Water Supply Systems	5
Kaunakakai	5
Ualapue	13
Kalae	13
Halawa	17
Private Systems	23
Molokai Ranch	23
Del Monte	30
Kalua Koi	33
Kawela Plantation	38
State Systems	39
Department of Hawaiian Home Lands (DHHL)	39
Molokai Irrigation System (MIS)	46
Projections of Future Water Use	52
Basis of the Projections	53
Division of the Island into Regions	53
Water Use Projection for the East Region	54
Water Use Projection for the Central Region	57
Kawela Plantation	57
DWS - Kaunakakai	57
DWS - Kalae	60
Del Monte - Kualapuu	60
Molokai Ranch - Kipu	60
Industrial Development - Lower Manawainui	60
DHHL - Kalamaula	62
DHHL - Kalae	62
DHHL - Hoolehua	62
Molokai Irrigation System (MIS)	62

TABLE OF CONTENTS
(continued)

	Page
Water Use Projection for the West Region	63
Kalua Koi Resort	63
Mauna Loa	63
Future Water Supply Options	68
Indicated System Improvements and Expansions	69
Basis for Evaluating Water Supply Options	69
Water Supply Options for the DWS-Kaunakakai System	71
Options Evaluated	71
Option 1: Use of the MIS	71
Option 2: Connection to the DHHL System	75
Option 3: Development of New Wells Inland of Kaunakakai	78
Option 4: Connection to the Ualapue System	81
Cost Comparison Among DWS-Kaunakakai Supply Options	84
Water Supply Options for West Molokai	88
Option 1: Expand Transmission Through the MIS	88
Option 2: Direct Purchase from the MIS	91
Option 3: Transmission Pipeline from Kalua Koi Wells to Mahana	93
Cost Comparison Among West Molokai Supply Options	96
Energy Recovery by Hydro-Generation	96
Hydro-Generation Potential at the 1.0 MG DWS-Kaunakakai Tank	98
Hydro-Generation Potential at the 200,000-Gallon DHHL-Kalamaula Tank	98
Hydro-Generation Potential Within the Kalua Koi System	98
Consolidation of Water Systems in Kalae-Kipu	103

LIST OF FIGURES

No.	Title	Page
1	Service Areas of Molokai Potable Water Systems	6
2	DWS Kaunakakai System from Kaunakakai to Kamiloloa	8
3	DWS Kaunakakai System from Kamiloloa to Kawela	9
4	Kaunakakai System Water Use in the 1970's.	10
5	DWS Ualapue System	14
6	Ualapue System Water Use in the 1970's	15
7	DWS Kalae System	18
8	Kalae System Water Use in the 1970's	19
9	DWS Halawa System.	21
10	Halawa System Water Use in the 1970's.	22
11	Schematic of the Molokai Ranch System's Mountain Sources .	25
12	Molokai Ranch Water System	26
13	Molokai Ranch Distribution Network in Mauna Loa.	27
14	Del Monte System, Kualapuu	31
15	Kalua Koi System, West Molokai	35
16	Kalua Koi System Water Use, 1977 to 1981	36
17	Kawela Plantation System	40
18	Department of Hawaiian Home Lands Water System	42
19	DHHL System Water Use in the 1970's.	44
20	Molokai Irrigation System.	49
21	MIS Water Use in the 1970's.	50
22	Projected Water Sales and Required Supply of the Ualapue System	56
23	Projected Water Sales and Required Supply of the Kaunakakai System.	59
24	Projected Water Sales and Required Supply of the Kalae System	61
25	Trend of Water Sales of the MIS Extrapolated to 1990 . . .	64
26	Supply Increments Required for the DWS-Kaunakakai Option of Continuing Use of the MIS	72
27	Supply Addition to the MIS as a Result of DWS-Kaunakakai Use	74

LIST OF FIGURES
(continued)

No.	Title	Page
28	Supply Increments Required for a Combined DHHL and DWS-Kaunakakai System	77
29	Water Level Measurements and Salinity Profile of Kakalahale Well 0700-01	79
30	Supply Increments Required for the DWS-Kaunakakai Option of Developing New Wells	80
31	Supply Increments Required for a Combined Kaunakakai and Ualapue System of DWS	82
32	Cost Comparison Among Supply Options for the DWS-Kaunakakai System	85
33	Comparative Costs of Diesel and Electric Power for Deep Well Pumping	86
34	Cost Comparison Among DWS-Kaunakakai Supply Options Based on Diesel Drive for Deep Well Pumping	87
35	Supply Increments Required for the West Molokai Option of Transmission through the MIS	90
36	Supply Additions to the MIS as a Result of Domestic Use in West Molokai	92
37	Supply Increments Required for the West Molokai Option of a New Transmission Pipeline	95
38	Cost Comparison Among Supply Options for West Molokai . .	97
39	Potential Hydro-Electric Energy Recovery at the 1.0 MG DWS-Kaunakakai Tank	99
40	Potential Hydro-Electric Energy Recovery at the 0.2 MG DHHL Tank in Kalamaula	101
41	Potential Hydro-Electric Energy Recovery in the Kalua Koi System	102
42	Schematic of DHHL, DWS, FAA, and Molokai Ranch Water Facilities in Kalae-Kipu	104
43	Supply and Use of the Meyer Estate's Waikalae and Waialala Tunnels, 1977 to 1981	105

LIST OF TABLES

No.	Title	Page
1	Department of Health Chemical Analyses of the Kaunakakai System	11
2	Summary of Molokai Water Systems Turbidity Measurements Submitted to the Department of Health, 1979 to 1982	12
3	Department of Health Chemical Analyses of the Ualapue System	16
4	Department of Health Chemical Analyses of the Kalae System	20
5	Summary of Molokai Ranch System Sources	24
6	Department of Health Chemical Analyses of the Molokai Ranch System	29
7	Department of Health Chemical Analyses of the Del Monte System	32
8	Department of Health Chemical Analyses of the Kalua Koi System	37
9	Department of Health Chemical Analyses of the Department of Hawaiian Home Lands System	45
10	MIS Supply Capability Defined by Division of Water & Land Development Operational Studies	48
11	Resident Population Enumerated in the Census of 1970 and 1980	55
12	Present and Projected Domestic Water Use in Molokai's Central Region	58
13	Potential Water Demand of the Kalua Koi Resort Based on Existing, Planned, and Developable Parcels	65
14	Existing and Projected Potable Water Use in Mauna Loa	67
15	Comparison of Projected Supply Requirements and Capacities	70
16	Pro-Rated Principle and Interest Payments on the Bureau of Reclamation Loan for DWS Use of the MIS	76
17	Pro-Rated Principle and Interest Payments on the Bureau of Reclamation Loan for West Molokai and DWS-Kaunakakai Use of the MIS	94

LIST OF TABLES
(continued)

No.	Title	Page
18	Economic Evaluation of Hydro-Generation at the 1.0 MG DWS-Kaunakakai Tank	100
19	Annual Amounts of Unused Meyer Tunnel Water Assuming 25,000 and 6,500 GPD Capacities of the Waikalae and Waialala Tunnels, Respectively	106
20	Annual Water Supply and Sales of the DWS-Kalae System for the Past Five Years	106

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ACRONYMS USED IN THIS REPORT

Acronym	Meaning
DHHL	Department of Hawaiian Home Lands, State of Hawaii
DLNR	Department of Land & Natural Resources, State of Hawaii
DOH	Department of Health, State of Hawaii
DOWALD	Division of Water & Land Development, DLNR, State of Hawaii
DWS	Department of Water Supply, County of Maui
GPD	gallons per day
GPM	gallons per minute
MGD	million gallons per day
MIS	Molokai Irrigation System
PPM	parts per million, approximately equivalent to milligrams per liter

SUMMARY OF THE MOLOKAI
WATER SYSTEMS PLAN

Molokai has abundant surface and groundwater on its east end. Most development is in the central and west parts of the island. Despite this logistic impediment, there are opportunities to minimize the cost of new water supply by making maximum use of facilities already constructed and in operation.

The island has ten major water systems run by seven operating entities. Their combined supply capacity is 15 MGD, more than double present requirements and greater than projected needs in 1990. Most systems are in close proximity and some are already interconnected. But their lack of operational integration prevents taking full advantage of facilities already in place. It is possible to integrate these systems for their mutual benefit and not simply to exploit those which currently have surplus capacity. This report presents a plan to accomplish this.

To enable development of the plan, all major systems were evaluated. Information on them is presented in three sections: (i) an inventory of existing facilities and current use; (ii) projections of future water use; and (iii) analyses of options to meet future water supply requirements. While the emphasis is on integration to minimize investment in new facilities and reduce the number of duplicate operating staffs, two other criteria are equally important: the ability of the Molokai Irrigation System ("MIS") to serve future agricultural needs must not be adversely affected; the capacity of the Department of Hawaiian Home Lands ("DHHL") system to supply its homesteaders must not be impaired.

INVENTORY OF EXISTING WATER SYSTEMS

County	Private Systems	State
o Kaunakakai	o Kalua Koi (domestic)	o Molokai Irrigation System (irrigation)
o Ualapue	o Molokai Ranch (domestic and irrigation)	o Department of Hawaiian Home Lands (domestic)
o Kalae	o Del Monte-Kualapuu (domestic)	
o Halawa	o Kawela Plantation (domestic)	

The water systems listed above are illustrated with capsule summaries on the fold-out map. Capacities and proximity of facilities are the principle opportunities of the Molokai Water Systems Plan. In addition to these physical features, legal constraints on the State systems need to be considered:

Molokai Irrigation System PL 84-984 ?

- The system was built for agriculture and its irrigation must have precedence over domestic use. Further, a $4.5 million Bureau of Reclamation loan specifies agricultural use exclusively. It is possible to renegotiate the loan agreement to include domestic use at a pro-rated interest adjustment.

- Chapter 175, Section 4 of the Hawaii Revised Statutes reserves up to two thirds of Waikolu Valley supply for the Department of Hawaiian Home Lands. Possible exercise of this right limits long-term commitment of supply to others even though a substantial surplus exists.

Department of Hawaiian Home Lands INTERIM USE ?

- Supply to DHHL homesteaders must have precedence over service to other systems or individuals.

- A 1978 amendment to the Hawaiian Homes Commission Act requires the water system to remain in the "...exclusive control of the department." While DHHL could benefit from the expertise of an integrated operating entity and also derive income from its installed facilities, any contractural arrangement must comply with the 1978 amendment.

FORECAST WATER SUPPLY REQUIREMENTS

Future domestic water requirements have been projected using census data, historic trends of water use, land development guidelines in the October 1981 "Molokai Community Plan", and specific plans of Kalua Koi, Molokai Ranch, and DHHL. Projected water demand of the MIS is based on an evaluation of the growth potential of agriculture.* Resulting forecasts through year 2000 are summarized in the table on the next page.

Comparison of forecast supply requirements with installed facilities identify surplus capacities in the MIS and DHHL and the County's Ualapue systems. It also depicts areas where new or expanded supply will be needed:

- Kaunakakai. The County-owned source can supply less than half of the current demand; use of the other source, the MIS, is without formal agreement. Forecast growth will require the County to acquire 1.3 MGD additional supply by 1990, 2.3 MGD by 2000. If acquisition of this supply is done without the perspective of island-wide integration, there are four options to consider:

---

* This study was conducted prior to the announcement that Del Monte's Molokai pineapple operation would be terminated. The plantation's use of the MIS has averaged 1.1 MGD over the last five years, about one third of the MIS' total sales. Its loss will eventually be replaced or even exceeded by water use of new agriculture on the Kualapuu lands. No specific projections based on Del Monte's closing are included in the study, however.

Molokai Island Water Use and Supply, 1982 to 2000

Water System	Supply and Use in 1982: Average Water Use (MGD)	Supply and Use in 1982: Installed Supply Capability (MGD)	Projection for 1990: Average Water Use (MGD)	Projection for 1990: Required Supply Capability (MGD)	Projection for 2000: Average Water Use (MGD)	Projection for 2000: Required Supply Capability (MGD)
County Department of Water Supply Red						
1. Kaunakakai Red	0.67	0.34[1]	0.99	1.64	1.62	2.67
2. Ualapue	0.15	0.48	0.21	0.34	0.31	0.50
3. Kalae	0.020	0.031[2]	0.027	0.044	0.040	0.065
4. Halawa	0.0023	0.014	0.003	0.005	0.004	0.007
Private Systems Blue						
1. Kalua Koi	0.85	2.00[3]	1.23	2.03	1.85	3.05
2. Molokai Ranch Green						
a. Kalae-Kipu	0.015		0.055	0.091	0.095	0.157
b. Manawainui	0.010		See Industrial-Lower Manawainui below			
c. Mauna Loa (domestic only)	0.075	0.23[4]	0.122	0.202	0.211	0.348
d. Irrigation	No data available		No projections made			
3. Kawela Plantation Red	Miscellaneous Construction Use	0.32	0.10	0.16	0.20	0.33
4. Del Monte Blue	0.08	0.08[5]	0.08	0.13	0.08	0.13
Industrial-Lower Manawainui	none at present		0.20	0.33	0.40	0.66
Department of Hawaiian Home Lands Green						
1. Kalamaula	0.075		0.230		0.39	
2. Hoolehua	0.145	1.15	0.220	0.79	0.30	1.19
3. Kalae	0.02		0.026		0.03	
Molokai Irrigation System	2.8	7.6	5.0	5.5	10.	11.

[1] DWS-owned supply in the Kaunakakai System is the Conant-Kawela Well. The balance of required supply is obtained from the Molokai Irrigation System without a formal agreement and at no cost.

[2] Kalae system capacity is given as the flowrate of the two Meyer Estate Tunnels. Water demand in excess of this can be pumped from the DHHL tank in Kauluwai.

[3] The capacity of the Kalua Koi System is currently limited by allowable transmission through the MIS. A 1975 agreement with the Molokai Irrigation System allows up to 2 MGD transmission for an annual rental of $45,000.

[4] Flow from the mountain sources varies from 80,000 to 550,000 gallons per day but records of it are not kept. Its 0.3 MGD estimated capacity based on augmenting flow from 10 million gallons storage. One quarter of this goes to Del Monte, the balance to Molokai Ranch.

[5] Del Monte's primary supply comes from the Molokai Ranch System and the sustainable amount given here is one quarter of the Ranch system's capacity. When that amount is insufficient, it is supplemented with water from its irrigation system.

1. Formalize use of the MIS, adding appropriate treatment, sharing interest on the Bureau of Reclamation loan, and participating in MIS source expansion when needed.

2. Connect to the DHHL system above Kalamaula, purchasing water at a price which covers its production cost and provides a financial incentive for DHHL, and sharing the cost of DHHL source expansion when needed.

3. Install new wells inland of Kaunakakai and outfit the existing Kakalahale well as a brackish blend with the new wells.

4. Install an 8.6 mile-long pipeline to Ualapue to connect to the County system there.

The pipeline to Ualapue is the most expensive of these alternatives. The other three options are economically competitive (refer to the cost curves on the next page).

- <u>Industrial Development in Lower Manawainui</u>. The "Molokai Community Plan" designates lower Manawainui as a site for industrial development; the first step toward this was construction of the new Molokai Electric power plant. The DHHL system in Kalamaula is the most appropriate water supply. The Molokai Ranch transmission pipeline is also nearby, but its supply potential is limited.

- <u>Kalua Koi and Mauna Loa on West Molokai</u>. Supply to the Kalua Koi Resort is limited to 2.0 MGD by terms of a transmission agreement with the MIS. Projected requirements of the Resort will exceed this limit by 1990.

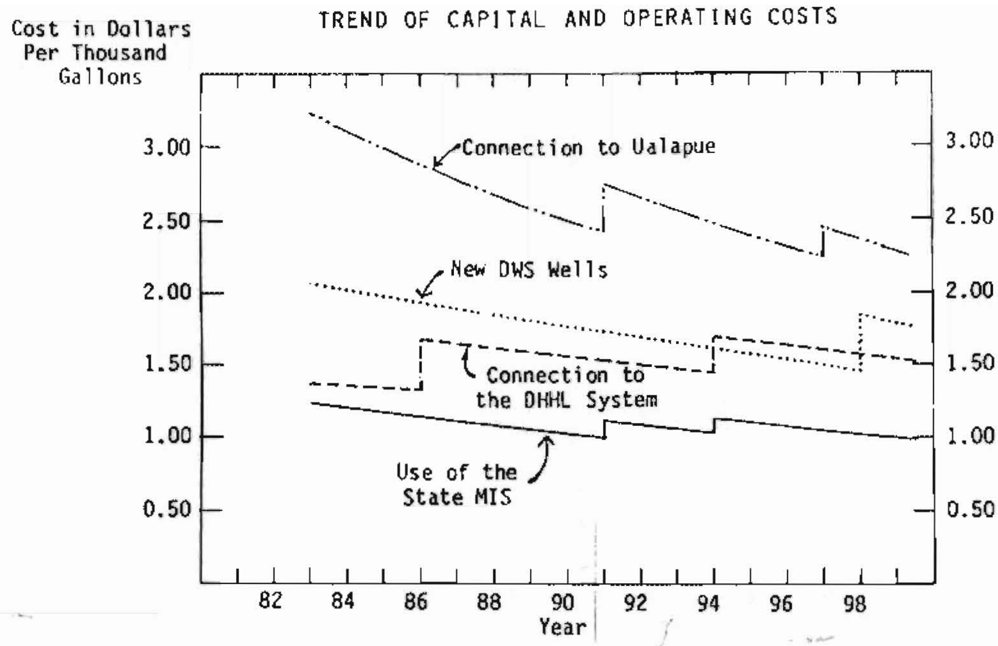
  As Kalua Koi Resort develops, so will the Manua Loa community. Forecast water use exceeds possible supply by the Molokai Ranch system unless the Ranch's irrigation use is curtailed. Further, turbidity of the Ranch's water often exceeds State drinking water standards and there are no plans to install appropriate treatment.

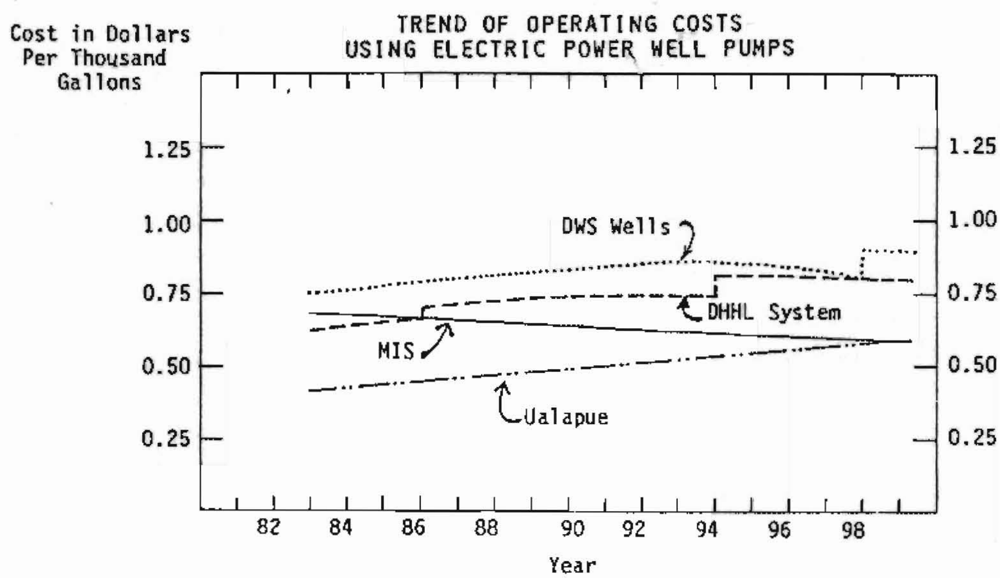
  In view of the lack of water resources in West Molokai, supply options for Kalua Koi Resort and Mauna Loa will necessarily include a long transmission link:

  1. Expand the transmission limit through the MIS from 2.0 to 4.0 MGD and share the cost of pipeline improvements within the MIS when needed.

  2. Purchase water directly from the MIS, making Kalua Koi's well a part of MIS sources and participating in other facilities additions when needed.

  3. Install a new transmission pipeline across Hoolehua from well sources east of Kualapuu to the Mahana pumping station.





Basis of the Cost Comparison

- o Capital investments would be financed by 13 percent bonds.
- o Operating costs are limited to pump and filter operation; no other manpower or administrative effort is included.
- o Pumps would be driven by electric motors; their costs are based on present Molokai Electric rate schedules.

The new transmission pipeline is the most costly alternative, whereas the options utilizing the MIS have nearly equivalent costs. High operating costs of all three options are unavoidable because of two pumping lifts, a 1,000-foot lift at the Kalua Koi well and an 800-foot lift at the Mahana pump station.

RECOMMENDED MOLOKAI WATER SYSTEMS PLAN

A Supply options which are limited to specific systems or areas cannot derive the advantages of an even broader integration. Properly done, such integration could enable systems with surplus capacity to derive income from it without making commitments as to the amount that would be sold. Systems with immediate or near-term supply needs could purchase from sources with lowest production costs and delay investments in new sources. And all systems could benefit by eliminating duplicate operating staffs.

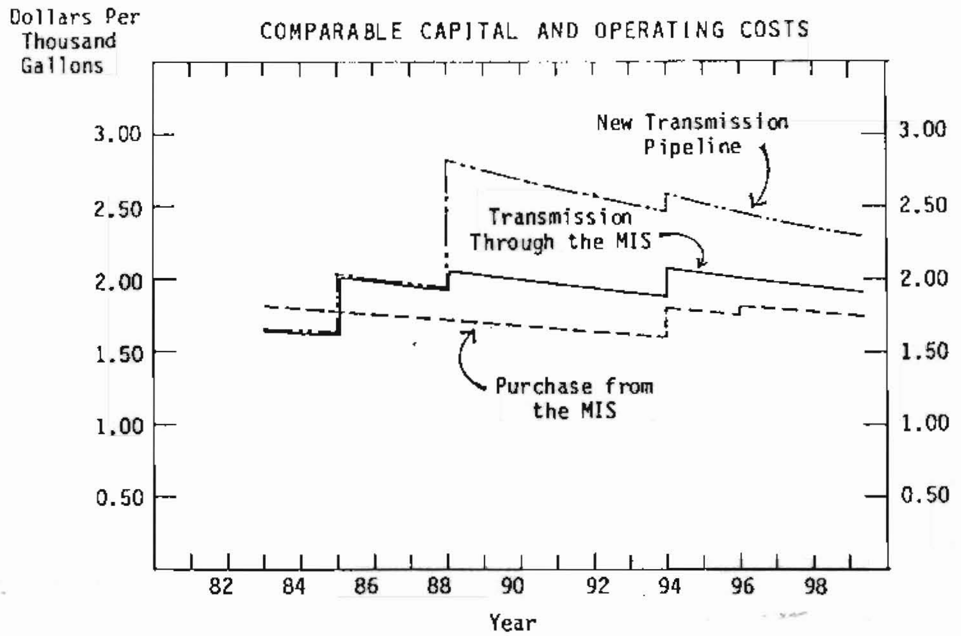
A plan to achieve this broad based integration should involve the following actions:

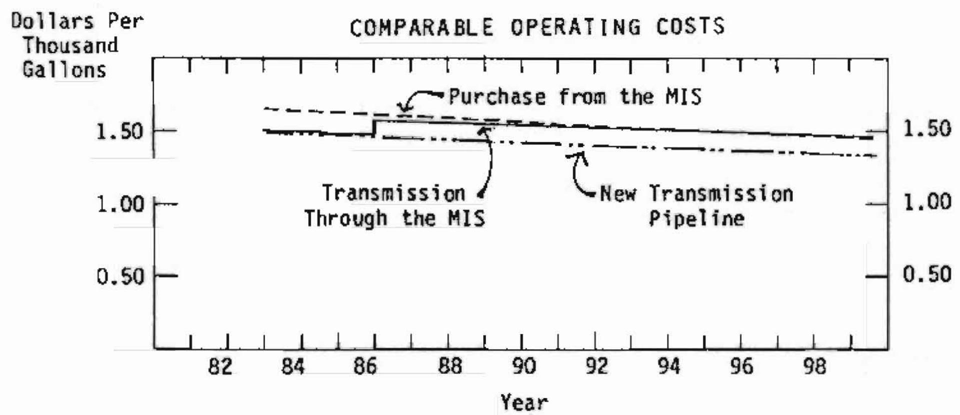
1. Domestic Use of the MIS. The MIS should renegotiate its Bureau of Reclamation Loan to allow sale of water for domestic use. Agricultural use would continue to have first priority and sales for domestic use would be limited to surplus water. A domestic price covering all costs and providing a financial incentive for the MIS would still be attractive to customers such as the DWS-Kaunakakai system.

2. DWS-DHHL Pipeline Interconnection. DWS should install a 12-inch pipeline between its 1.0 MG Kaunakakai tank and the DHHL transmission pipeline above Kalamaula. Estimated cost is $810,000. Firm supply available to DWS would be comprised of its own Kawela well and the portion of DHHL well capacity in excess of DHHL's needs. DWS should be obligated to share the cost of DHHL source additions when needed. The first of these would be to replace the pump in DHHL's older well.

3. (A) Priority Use of Sources Available to the DWS-Kaunakakai System. Sources would be utilized in order of least cost and availability: (i) water pumped from the Kawela shaft; (ii) water purchased from the MIS; (iii) DHHL system water purchased and/or exchanged for operating expertise and manpower. Installation of treatment facilities for MIS water is not warranted. On occasions when MIS turbidity is too high, DHHL water can be used instead.

4. (A) DWS-DHHL Operating Contract. DWS should enter into an operating contract with DHHL which complies with the exclusive control provision of the Hawaiian Homes Commission Act. This would enable maximum use of the low cost Meyer tunnels and Waihanau source to be achieved. DHHL presently has a number of non-homesteader customers who buy water at the subsidized homesteader rate. Their purchase price should be immediately adjusted upward. *





Basis of the Cost Comparison

- Capital investments would be financed by 13 percent bonds.

- Operating costs are limited to pump and filter operation; no other manpower or administrative effort is included.

- Pumps would be driven by electric motors; their costs are based on present Molokai Electric rate schedules.

A

5. Installation of Treatment Facilities in Mauna Loa. Molokai Ranch should install appropriate treatment facilities in Mauna Loa and construct a pipeline connection to the Kalua Koi system. These improvements will make a unified West Molokai system possible.

6. DWS Assumption of Unified West Molokai System. DWS should operate the combined Kalua Koi - Mauna Loa system. Its supply sources, in order of least cost and availability, would be: (i) water purchased from Molokai Ranch; (ii) MIS surplus water purchased at Mahana and pumped to the west end; (iii) Kalua Koi well water conveyed through MIS pipelines under a DWS-MIS rental agreement. Operating costs to supply customers in Mauna Loa and Kalua Koi will exceed DWS' County-wide sale price. A surcharge paid by Kalua Koi Corporation or resort customers would be appropriate.

7. Obligation of Kalua Koi Resort to make Future Capital Expenditures. Kalua Koi Corporation should be obligated to install new wells and share the cost of new MIS pipelines in Hoolehua when needed. This would ensure adequate supply to its Resort and Mauna Loa without adversely affecting distribution to MIS irrigation customers in Hoolehua.

Implementing these recommendations would enable separate systems to evolve into two operating entites, the MIS and DWS. It is ironic but unaoidable that many complex relationships are required to achieve simplicity, efficiency, and mutual benefit. state should exercise leadership

FUTURE WATER SUPPLY COSTS

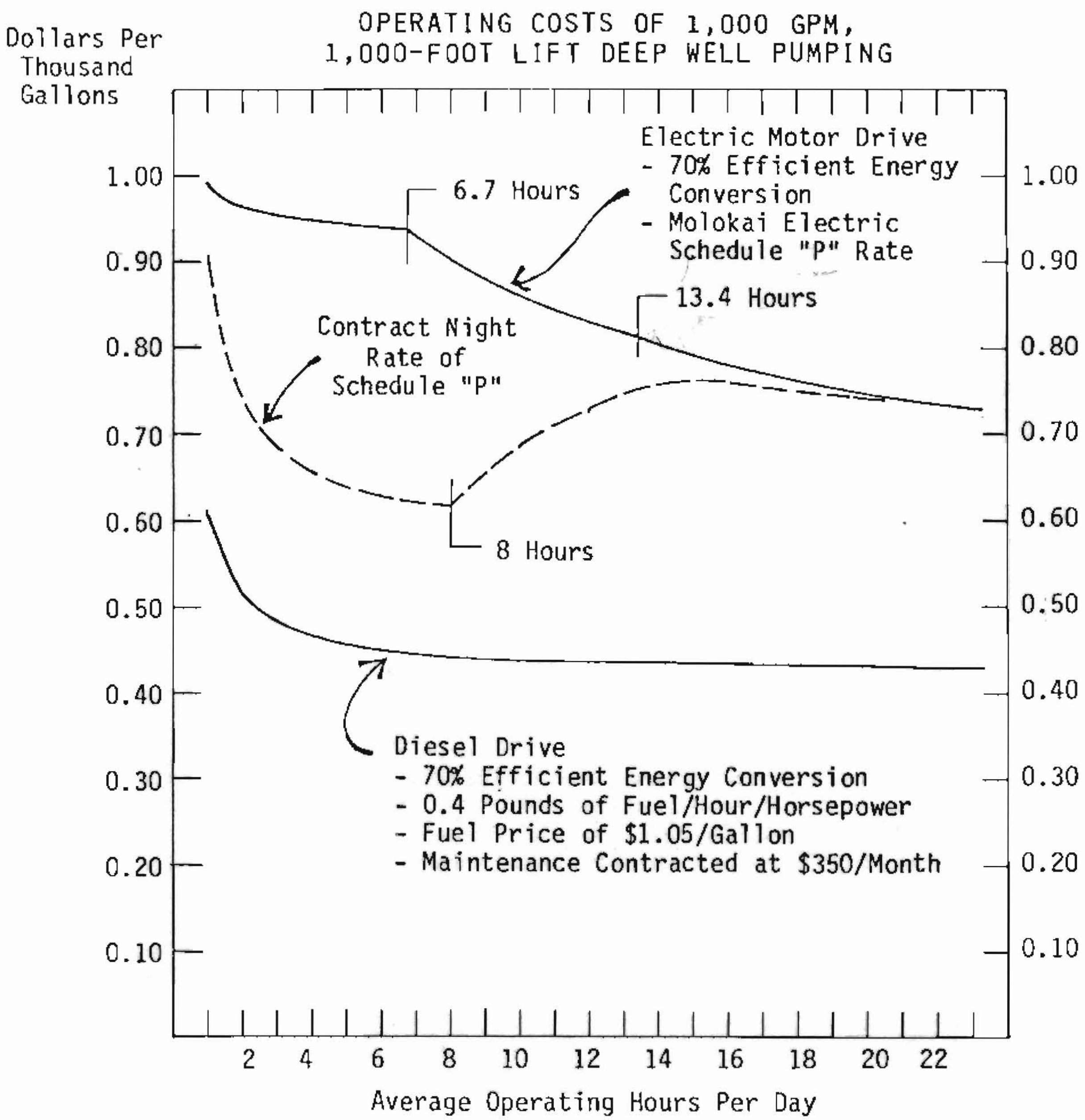
Future Molokai water costs, even utlizing system integration, will be high. Molokai Electric has the highest rates in the State and substantial well and booster pumping lifts are unavoidable. There are ways to reduce this cost, however. One way is to use direct diesel drives on pumps. As an example, for a pump lifting 1000 feet and operating 8 to 12 hours a day, diesel drive would be half the cost of an electric motor.

Another way to reduce operating cost is to recover energy using in-line hydro-electric generators. Recent development of automatic control valves to maintain synchronous speed has substantially reduced the initial cost of generating units. Recovered hydro-electric energy could be sold to Molokai Electric, but a far greater return would be achieved if it is used on-site or in near proximity.

There are several sites where hydro-electric generators could recover energy which is now wasted by pressure breakers. None have on-site power uses which would justify immediate installation of generating units, but the potential of each site should be considerd for the future:

- There is a 700-foot drop from the MIS transmission pipeline to the 1.0-million gallon Kaunakakai tank. (Figure 39, page 99 in the report illustrates its hydropower potential.)

COMPARISON OF DIESEL DRIVE AND ELECTRIC POWER FOR DEEP WELL PUMPING



- There is a drop of 750 feet from DHHL system wells to the tank above Kalamaula (Figure 40, page 101). If DWS-Kaunakakai is connected to the DHHL system, the amount of water from which to recover energy will be increased several fold.

- There is a 400-foot drop from Kalua Koi reservoirs on top of Mauna Loa to a pressure breaker along the Resort's access road and another 450-foot drop from the pressure breaker to Kalua Koi's filters and 2.0-million gallon tank (Figure 41, page 102).

MOLOKAI ISLAND WATER SYSTEMS - 1982
MOLOKAI WATER SYSTEMS PLAN
DEPT. OF WATER SUPPLY
COUNTY OF MAUI
BELT, COLLINS & ASSOCIATES
DECEMBER 1982
PACIFIC OCEAN
KAIWI CHANNEL
KALUA KOI
FILTERS & 2MG TANK
DEPT. OF HAW'N HOME LANDS
HOOLEHUA
(SHOWN DASHED)
MOLOKAI IRRIGATION SYSTEM
MAHANA PUMP STATION
5MG OPEN TANKS
5MG OPEN TANK
MOLOKAI RANCH
(SHOWN DASHED)
DEL MONTE
KALAE
0.1MG TANK
WAIKOLU DIVERSION
DIVERSION & PUMP
WEIR BOX
KAMOKU INTAKE
KAWELA INTAKES
WEST PORTAL OF TUNNEL
DEPT. OF HAW'N HOME LANDS
KALAMAULA
0.2 MG TANK
1MG TANK
KAUNAKAKAI
KAWELA PLANTATION
KAWELA SHAFT
UALAPUE
UALAPUE SHAFT
HALAWA
CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL
COUNTY SYSTEMS
Kaunakakai. The County's largest system now supplies an average of 670,000 gallons per day. About 45 percent of this comes from the County-owned Kawela well. The balance is obtained from the State's Molokai Irrigation System.
Ualapue. This 9.7 mile-long system supplies an average of 150,000 gallons per day. Its single source, the County-owned Ualapue well, can provide three times this amount.
Kalae. Water sales of this system average 20,000 gallons per day. About 90 percent of its supply comes from two Meyer tunnels. The balance is purchased from the Department of Hawaiian Home Lands' Kauluwai tank.
Halawa. This system consists of a stream diversion and 1½-inch galvanized transmission pipeline. Water flows directly to valley customers without storage or treatment.
PRIVATE SYSTEMS
Kalua Koi. Kalua Koi pumps well water into the Molokai Irrigation System and takes it out at Mahana. Water is then pumped to Mauna Loa and it flows from there by gravity to the resort. It is 18 miles between well source and the resort.
Molokai Ranch (shown dashed above). Sources are stream diversions in upper Kawela. Water flows entirely by gravity across central Molokai to Mauna Loa. Maximum supply is 550,000 gallons per day in the rainy season. Storage reservoirs augment low summer flows to maintain a supply of about 300,000 gallons per day in the summer.
Kawela Plantation. The system was built for domestic use within its 200-lot agricultural subdivision. Supply comes from three, small-capacity wells. A separate, brackish water system can supply irrigation use.
Del Monte - Kualapuu. Its source is primarily Moloki Ranch water but it is augmented by the Molokai Irrigation System when needed. Water is chlorinated and then filtered prior to distribution within Del Monte's Kualapuu community.
STATE SYSTEMS
Department of Hawaiian Home Lands (shown dashed above). Its sources are Waihanau surface water and two 1000-foot wells. Combined capacity is 1.1 to 1.7 million gallons per day (depending on how capacity is defined); current use is only 25 to 30 percent of this. It has two major distribution areas, Kalamaula and Hoolehua, and also supplies the junior and senior high schools and Molokai Airport.
Molokai Irrigation System. Waikolu stream, well, and tunnel sources, augmented by the 1.4 billion gallon Kualapuu reservoir, can supply 7.6 million gallons per day. Currently, 3700 agricultrual acres are irrigated by this system. Usage amounts to 35 to 40 percent of source capacity.

INTRODUCTION

Ten water systems on Molokai were considered in this planning study. Four of these are owned and operated by the County Department of Water Supply, four are private, and two are owned and operated by State agencies. It is the intent of this study to create an up-to-date inventory of these systems, to project future requirements of each, and to identify the best solutions to meet future requirements. Solutions which can best minimize costs and optimize resources are, in some cases, in conflict with present government regulations and financial commitments. These conflicts are identified herein. Their resolution will require cooperative efforts of a number of government agencies and private entities.

This study has been undertaken for the Maui County Department of Water Supply. Kalua Koi Corporation and Molokai Ranch, as owner-operators of large water systems, also provided funds for the study. It is the intention of these companies and the Department of Water Supply to explore efficiencies possible through economies of scale and elimination of duplicate facilities and operating staffs. There are substantial source, transmission, and distribution capacities which cannot be fully utilized if the various systems remain under separate control.

The main body of the report is organized into three sections. The first is an inventory of the facilities, operation, and trends of water use of each system. The second projects the future water demands based on expectations of the systems' operators, objectives set forth in the 1981 Molokai Community Plan, and development plans of government and large landowners. The third section formulates and evaluates future water supply options. The study's conclusions, reflecting the responses of government agencies and private entities to future water supply options as well as the analyses of Belt, Collins & Associates, are presented in the Summary section in the front of this report.

INVENTORY OF EXISTING
WATER SYSTEMS

WATER SYSTEMS INVENTORIED

Systems inventoried for this study and considered in future water supply options are:

County Systems	Private Systems	State Systems
1. Kaunakakai	1. Molokai Ranch	1. Molokai Irrigation System
2. Ualapue	2. Del Monte	2. Department of Hawaiian Home Lands
3. Kalae	3. Kalua Koi Corporation	
4. Halawa	4. Kawela Plantation	

Areas supplied by these systems are shown on Figure 1. The State's Molokai Irrigation System was built and is operated for agricultural use. The Molokai Ranch system serves agricultural and domestic purposes. All of the other systems are primarily for domestic use.

MAUI COUNTY DEPARTMENT OF WATER SUPPLY SYSTEMS

The Department of Water Supply ("DWS") owns and operates four physically distinct systems, each of which originated as a private system which the County assumed sometime in the 1940's or 1950's. DWS has five employees on Molokai and an administrative office in Kaunakakai. Water is sold at $0.79 per thousand gallons for domestic and agricultural use plus a nominal monthly meter charge.

Kaunakakai

Sources. The Kaunakakai System was originally built by Molokai Ranch but was substantially improved by DWS when it assumed it in 1946. Early sources included dug well 30, a pipeline from the Molokai Ranch mountain system, and Makaeleele Dam at elevation 2365 feet above Kalae. All were of limited yield and are no longer in use. Present sources are the Conant-Kawela well (0457-01) and a tap from the State's Molokai Irrigation System ("MIS").

The Conant-Kawela well was constructed in 1920-21. It's a Maui-type well with a 4' x 4' vertical shaft about 38 feet deep and two horizontal skimming tunnels of 229 feet total length. The water level is typically 1.8 to 2.2 feet above mean sea level but has been as low as 1.4 feet during extended dry periods. A recent level recording by S.P. Bowles shows a maximum tidal-induced groundwater fluctuation of 0.1 feet. The well is now outfitted with two line shaft turbine pumps, one rated at 300 gallons per minute ("GPM") (installed in 1951) and the other at 350 GPM (installed in 1963). S.P. Bowles' recording shows that a drawdown in the shaft of 0.25± feet occurs during pumping. Pumpage has averaged 0.3 million gallons per day ("MGD") over the last 10 years. The salinity has fluctuated seasonally and with pumpage but has always been well within the bounds of potable quality.

Maximum sustainable yield of potable quality water is probably not more than 0.40 to 0.45 MGD. A 27-day pump test in December 1946 to January 1947 at 1.2 MGD resulted in the chloride level rising from about 30 mg/l to over 300 mg/l. This test rate was above the sustainable yield. Impending use of nearby wells by the Kawela Plantation project (detailed subsequently in this inventory section) means that County pumpage from its Kawela well should be kept at about its present level.

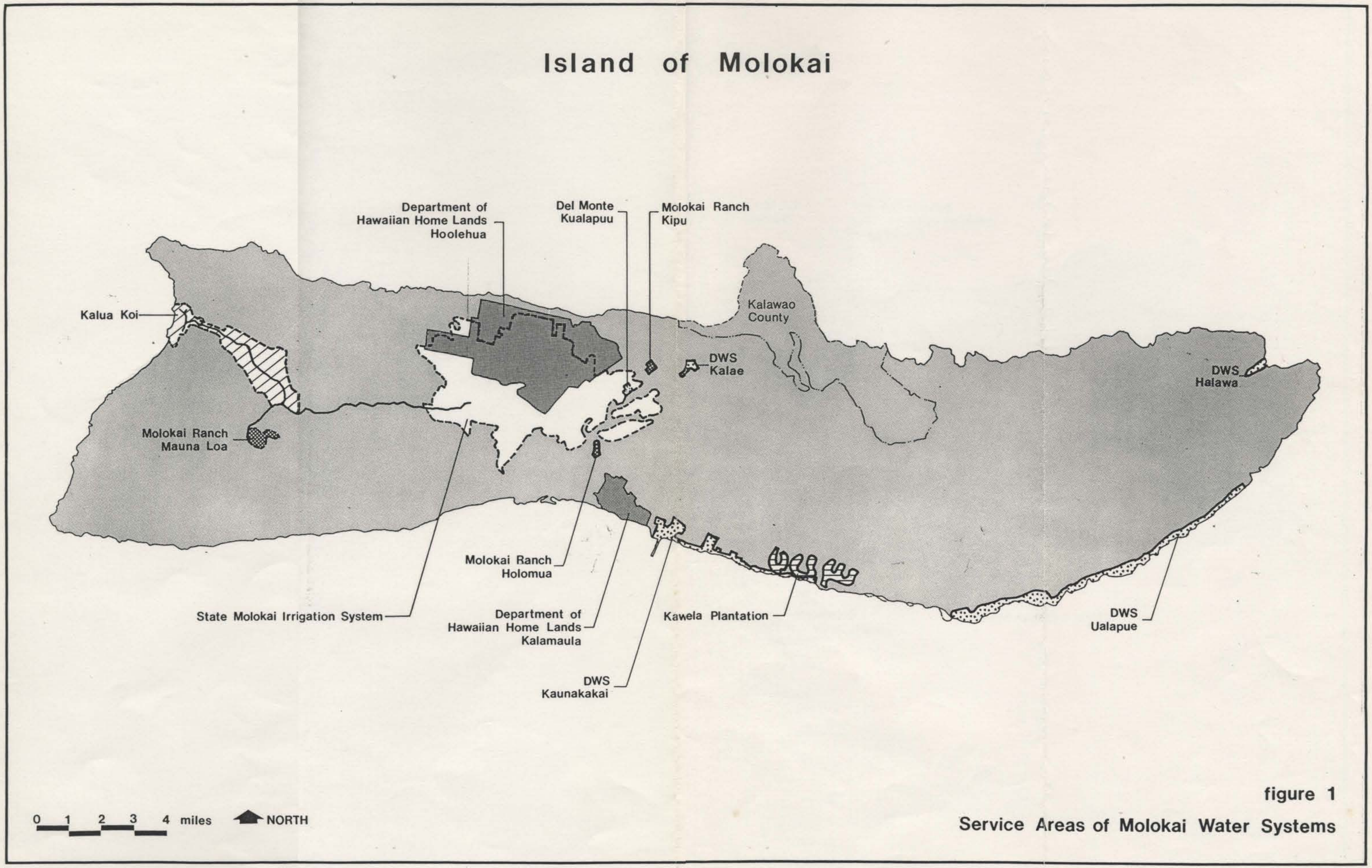


figure 1

Service Areas of Molokai Water Systems

Connection to the State's MIS transmission pipeline was made in July 1971. After several modifications, the tap is now an 6-inch pipeline connected to a distribution box on the transmission pipeline at elevation 950 feet. Flow rate control, screening, and chlorination occur along this pipeline at elevation 435 feet before the water is delivered to a storage tank above Kaunakakai. Connection to the State system was originally made so it could serve as a standby source. However, its water use has grown over the decade of the 1970's to an average of over 0.3 MGD currently. DWS receives the water without charge and without a formal usage agreement.

Storage and Distribution. Figures 2 and 3 show the current storage and distribution network. It serves a 5.1-mile long segment of the coast from Kaunakakai to Kawela Gulch. Primary storage is in the 1.0 MG tank at elevation 250 feet above Kaunakakai. By a float switch, its water level controls inflow of MIS water. Pumpage from Kawela Shaft at the other end of the system is controlled by the level in the 0.1 MG tank in Kanoa. At elevation 260 feet, this tank is higher than the one in Kaunakakai. Unless DWS personnel manually control the two sources, the elevation difference of the storage tanks and hydraulic friction losses throughout the system determine the relative inputs of water from the two sources. Recent pipeline additions in Kaunakakai have reduced frictional resistance there and have resulted in more usage of MIS water than previously.

Figure 4 summarizes water service through the 1970's. Water sales increased at 7 percent per year, a result of increases in service connections (at just over 4 percent per year) and water use per service connection (at 2.5 percent per year). Kawela well pumpage has been relatively constant; virtually all of the increasing water use has been met by the MIS source.

Water Quality. As shown by State Department of Health ("DOH") analyses summarized on Table 1, the chemical quality of Kaunakakai system water is excellent. During rainy periods, MIS water, a surface source, has high turbidity. On these occasions, DWS can reduce its impact by closing valves, limiting the area supplied by MIS water to upper Kaunakakai town. Table 2 summarizes turbidity measurements by DWS over the last three years. Quality standards have been exceeded on four occasions since January 1979. Without isolation of MIS water during rainy periods, the frequency of exceedence would have been higher.

Constraints. Continual use of MIS water for domestic consumption would require appropriate coagulation and filtration treatment to remove turbidity. More important than the question of quality is whether or not the County can continue using MIS water at all. The system was built with State funds and a Federal Bureau of Reclamation loan; both funding sources stipulated agricultural use for the system. To formalize DWS use, agreements between DWS and the State and between the State and the Bureau of Reclamation would be required. It would have to be demonstrated that DWS use would not preempt MIS irrigation supply to Hoolehua. Also, the interest rate on a portion of the Bureau of Reclamation loan would be adjusted upward.

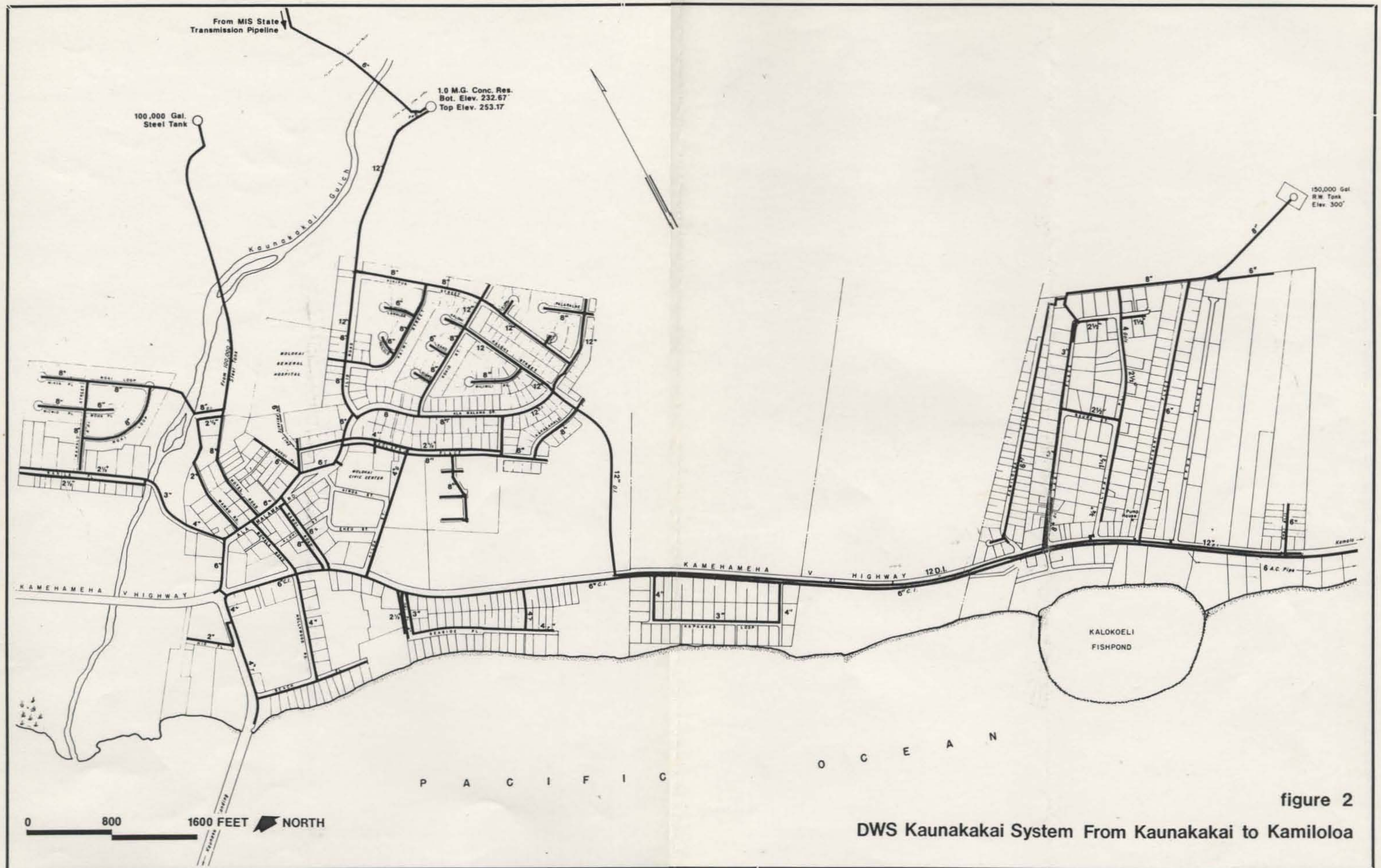


figure 2

DWS Kaunakakai System From Kaunakakai to Kamiloloa

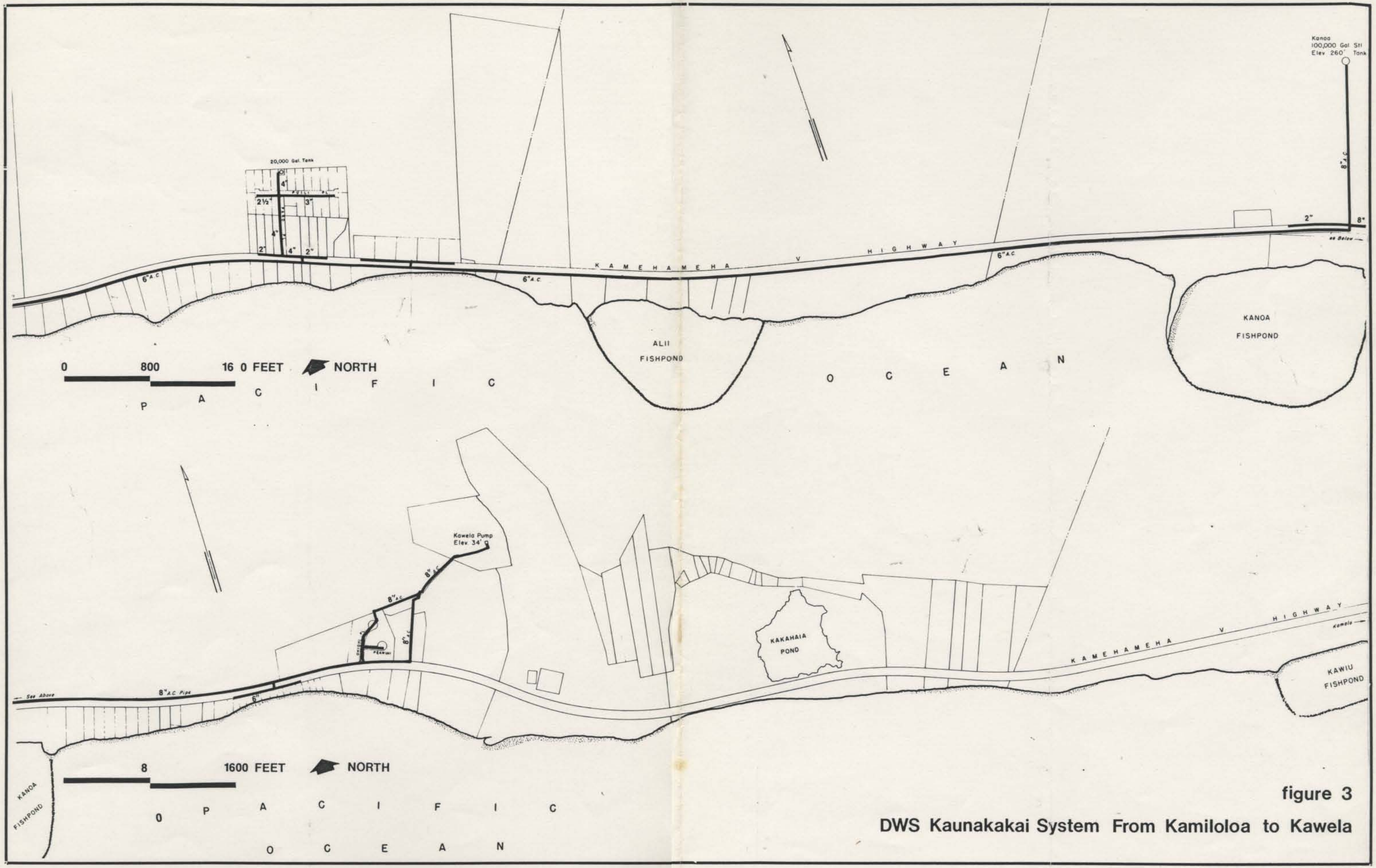
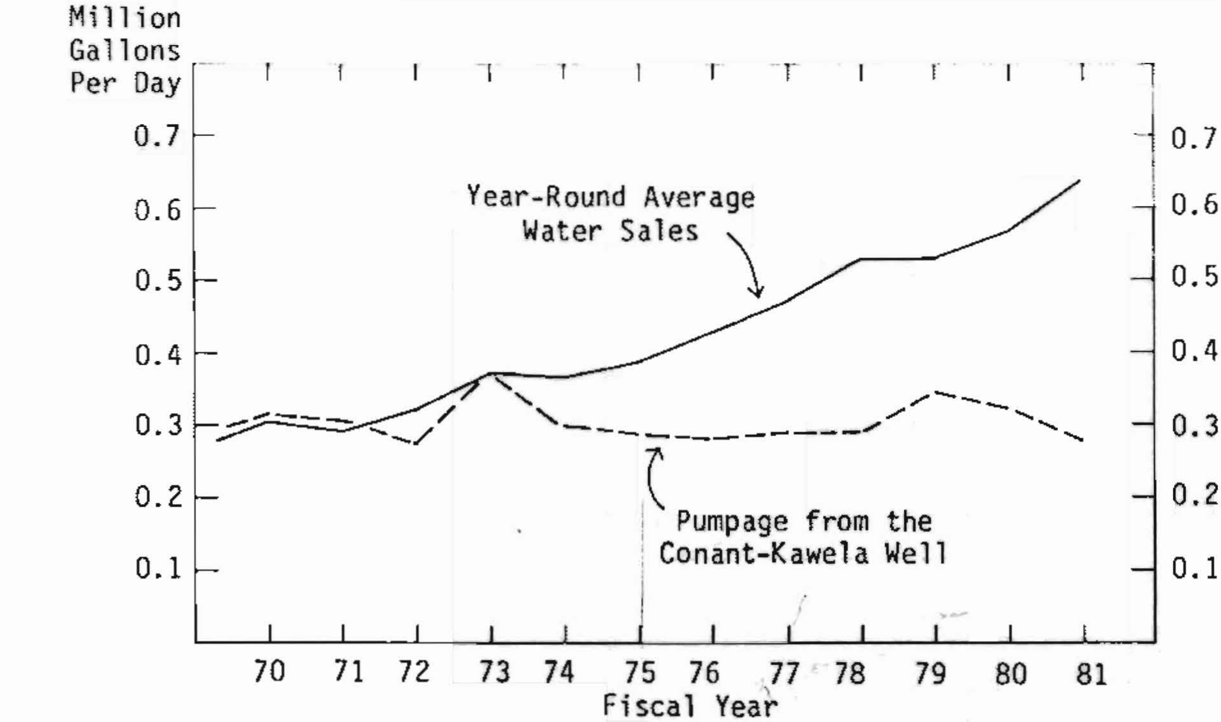
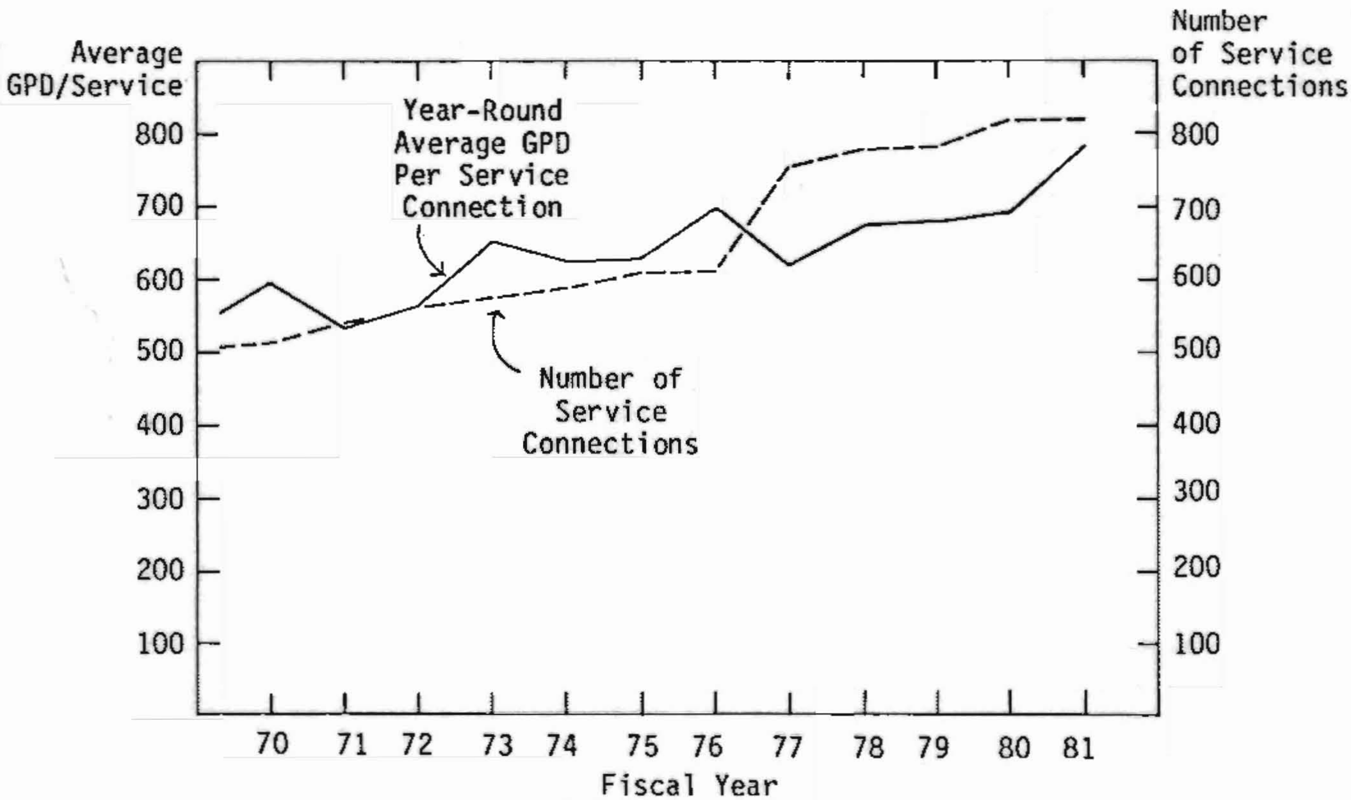


figure 3

DWS Kaunakakai System From Kamiloloa to Kawela





Source: Annual Reports of the
Dept. of Water Supply

Figure 4. Kaunakakai System Water Use in the 1970's

TABLE 1. Department of Health Chemical Analyses of the Kaunakakai System (DOH System No. 234)

Constituent	Units	Maximum Allowable Contaminant Levels*	Date of Sample 12/11/78	7/24/79	9/3/80	8/17/81
Arsenic	mg/l	.05	.02	.02	.02	.02
Barium	mg/l	1	.8	.8	.8	.8
Cadmium	mg/l	.01	.005	.005	.005	.005
Chromium	mg/l	.05	.01	.01	.01	.01
Lead	mg/l	.05	.01	.02	.02	.02
Mercury	mg/l	.002	.0005	.0005	.0005	.0005
Nitrate (as N)	mg/l	10	.23	.39	.49	.43
Selenium	mg/l	.01	.01	.01	.01	.01
Silver	mg/l	.05	.03	.03	.03	.03
Flouride	mg/l	1.4	.2	.2	.2	.2
Chloride	mg/l	250**	15	12	12	14
Sodium	mg/l	none	--	9.9	8.5	9
Total Dissolved Solids	mg/l	500**	75	83	86	85

* Maximum contaminant levels are established by Federal National Interim Primary Drinking Water Standards and State Department of Health Regulations (Chapter 49).

** Secondary standards.

Source: Department of Health Drinking Water Program

TABLE 2. Summary of Molokai Water Systems Turbidity Measurements Submitted to the Department of Health, 1979 to 1982 (in Turbidity Units)

Date		Del Monte			Hawaiian Homes			Molokai Ranch			DWS - Kaunakakai			Kaluakoi		
Year	Month	Monthly Average	Times Two Days Over 5th	Exceeds Stds?	Monthly Average	Times Two Days Over 5th	Exceeds Stds?	Monthly Average	Times Two Days Over 5th	Exceeds Stds?	Monthly Average	Times Two Days Over 5th	Exceeds Stds?	Monthly Average	Times Two Days Over 5th	Exceeds Stds?
1979	Jan	.8	0		3.3	7	Yes	.9	0		2.6	2	Yes	.5	0	
	Feb	.7	0		7.9	23	Yes	.9	0		.9	0		.5	0	
	Mar	.6	0		3.9	5	Yes	.9	0		.9	0		.5	0	
	Apr	.6	0		3.3	5	Yes	.9	0		.7	0		.5	0	
	May	.4	0		3.1	0	Yes	.94	0		.4	0		.5	0	
	Jun	.26	0		1.4	0	Yes	.94	0		.5	0		.5	0	
	Jul	.32	0		.7	0		.9	0		.5	0		.5	0	
	Aug	.3	0		.5	0		.9	0		.5	0		.5	0	
	Sep	.28	0		.5	0		.96	0		.3	0		.5	0	
	Oct	.4	0		.5	0		.97	0		.4	0		.5	0	
	Nov	.6	0		.6	0		.98	0		1	0		.5	0	
	Dec	.7	0		3.3	5	Yes	.95	0		.9	0		.5	0	
1980	Jan	1	0		13.2	30	Yes	.96	0		.12	0	Yes	.5	0	
	Feb	.5	0		5.7	5	Yes	.96	0		.6	0		.5	0	
	May	.64	0		10.7	30	Yes	1.2	0	Yes	1.5	0	Yes	.5	0	
	Apr	.56	0		9.3	14	Yes	1.2	0	Yes	.8	0		.5	0	
	May	.5	0		1.4	0	Yes	.9	0		.6	0		.5	0	
	Jun	.53	0		.65	0		1.2	0	Yes	.5	0		.5	0	
	Jul	.5	0		.6	0		1	0		.5	0		.5	0	
	Aug	.4	0		.6	0		1.1	0	Yes	.5	0		.5	0	
	Sep	.4	0		.3	0		1.3	0	Yes	.3	0		.5	0	
	Oct	.6	0		.3	0		1.7	0	Yes	.5	0		.5	0	
	Nov	.4	0		.35	0		2	0	Yes	.4	0		.5	0	
	Dec	.5	0		.36	0		2.5	0	Yes	.5	0		.5	0	
1981	Jan	.4	0		.29	0		2.6	0	Yes	.4	0		.5	0	
	Feb	.6	0		.27	0		2.8	0	Yes	.5	0		.5	0	
	Mar	1	0		0	0		1	0		1	0		0	0	
	Apr	1	0		0	0		1	0		.7	0		0	0	
	May	1	0		0	0		1	0		.9	0		1	0	
	Jun	1	0		3	0		N/A	N/A		.4	0		1	0	
	Jul	0	0		1	0		3	0	Yes	0	0		1	0	
	Aug	1	0		0	0		3	0	Yes	1	0		N/A	N/A	
	Sep	0	0		0	0		3	0	Yes	0	0		0	0	
	Oct	1	0		0	0		3	0	Yes	0	0		1	0	
	Nov	1	0		0	0		2	0	Yes	1	0		1	0	
	Dec	1	0		0	0		3	2	Yes	1	0		1	0	
1982	Jan	1	0		0	0		3	0	Yes	2	0	Yes	1	0	
	Feb	1	0		0	0		4	0	Yes	1	0		0	0	

Source: Department of Health Drinking Water Program

Ualapue

Sources. Original sources of this system included Kahananui Stream and Spring, Ahaino Spring, Waialua Stream, and dug well 42. Pipeline projects in the 1938 to 1953 period linked previously separate community water systems and enabled the Ualapue Maui-type well (0449-01) to become the sole source of supply. Its vertical shaft is 41 feet deep and is fed by 180 feet of skimming tunnels. Pumpage in recent years has averaged 150,000 to 175,000 GPD, far less than the capacity of either of its 500 GPM line shaft turbine pumps.

Water level in the vertical shaft is typically in the 3.0 to 3.5 feet above sea level range. There has been very little salinity fluctuation seasonally or due to pumpage. A 1970 pump test by the State Division of Water and Land Development at 0.43 MGD produced only 0.1 ft. of drawdown and no salinity change. This pumping rate is equivalent to more than twice current water usage. It is also less than the well's maximum sustainable yield of potable water.

Storage and Distribution. Figure 5 illustrates the 9½-mile long pipeline system which extends from Kamalo to Moanui Stream. Most of this distance is served by a 12-inch distribution main along Kamehameha V Highway. The 1.0 MG concrete storage tank at elevation 250 feet above the well in Ualapue is substantially higher than two older and much smaller (50,000 and 47,000 gallons) tanks of the system. In effect, the level of the higher tank locks out the two lower ones, reducing them to a standby basis.

Water use for the system through the decade of the 1970's is presented on Figure 6. Present water sales are in the 140,000 to 150,000 GPD range, the result of a 6 to 7 percent per year growth rate in the last ten years. Use rate per service connection has increased at 4.5 percent per year and the number of service connections at 1.9 percent per year.

Water Quality. The excellent chemical quality of the system's water is demonstrated by annual DOH analyses presented on Table 3. Because supply is from a well, turbidity measurements are not required. There have been occasional positive coliform counts. This has occurred four times in the quarterly analyses by DOH over the last two years.

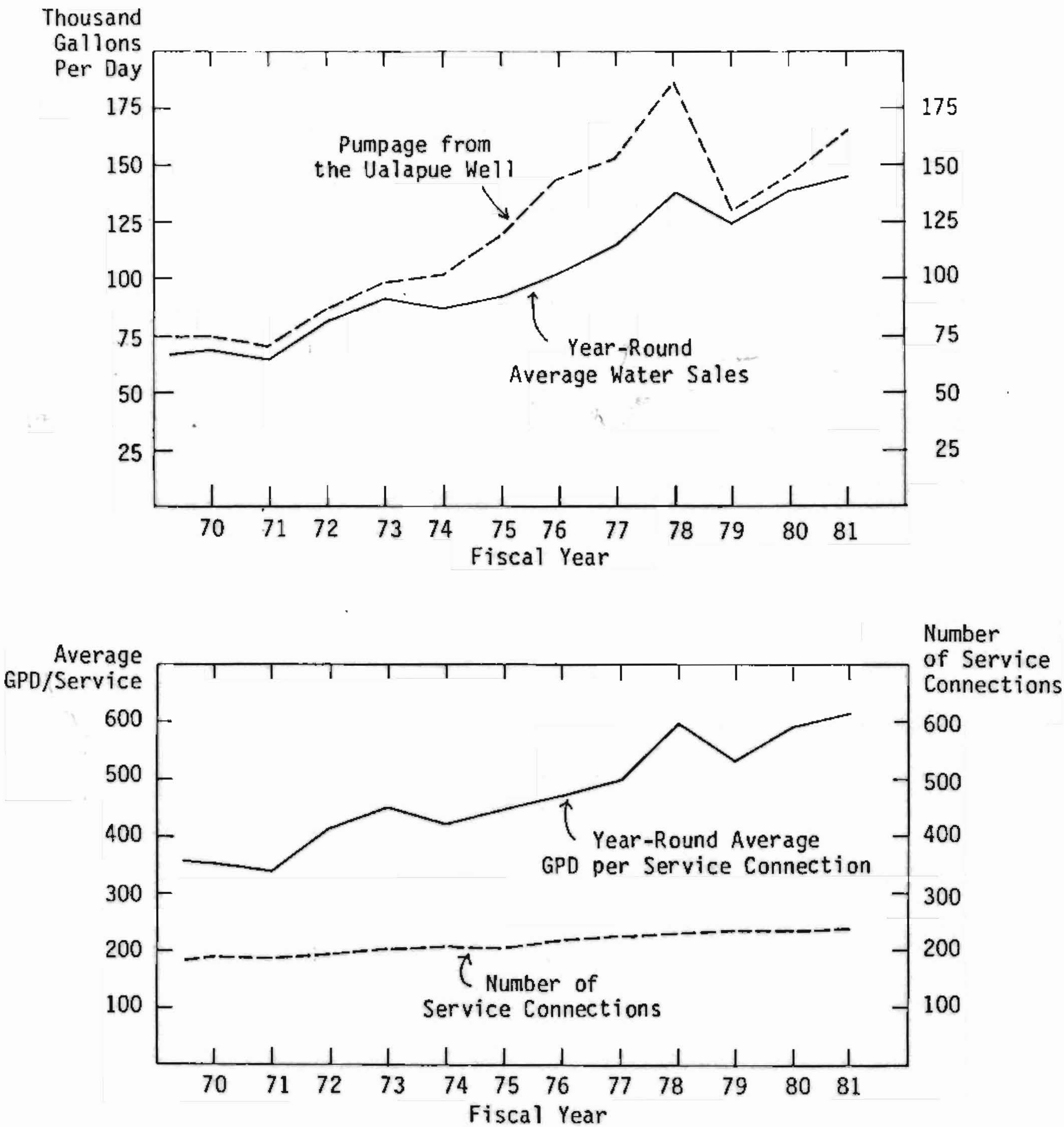
Constraints. The small pipelines beyond the 12-inch pipeline in Kamalo result in low pressures to customers at the west end of the system. Otherwise, supply, storage, and distribution are more than adequate for present and projected use.

Kalae

Sources. Primary sources of supply are the Waikalae and Waialala tunnels at elevations 1715 and 1625 feet, respectively. The tunnels yield perched water and deliver it to the system by gravity. This water is purchased from the R.W. Meyer Estate, owner of the tunnels, for $0.15 per thousand gallons. Purchases have averaged 28,000 GPD to the County system in the last several years.

figure 5

DWS Ualapue System



Source: Annual Reports of the Dept. of Water Supply

Figure 6. Ualapue System Water Use in the 1970's

TABLE 3. Department of Health Chemical Analyses of the Ualapue System (DOH System No. 233)

Constituent	Units	Maximum Allowable Contaminant Levels*	Date of Sample			
			12/11/78	8/20/79	9/3/80	8/17/81
Arsenic	mg/l	.05	.02	.02	.02	.02
Barium	mg/l	1	.8	.8	.8	.8
Cadmium	mg/l	.01	.005	.005	.005	.005
Chromium	mg/l	.05	.01	.01	.01	.01
Lead	mg/l	.05	.01	.02	.02	.02
Mercury	mg/l	.002	.0005	.0005	.0005	.0005
Nitrate (as N)	mg/l	10	.24	.27	.36	.31
Selenium	mg/l	.01	.01	.01	.01	.01
Silver	mg/l	.05	.03	.03	.03	.03
Flouride	mg/l	1.4	.2	.2	.2	.2
Chloride	mg/l	250**	63	59	57	60
Sodium	mg/l	none	N/A	45	42	42
Total Dissolved Solids	mg/l	500**	218	211	218	213

* Maximum contaminant levels are established by Federal National Interim Primary Drinking Water Standards and State Department of Health Regulations (Chapter 49).

** Secondary standards.

Source: Department of Health Drinking Water Program.

The other supply source, used on an as needed basis, is the Department of Hawaiian Home Lands ("DHHL") system. Water is purchased at the 1.0 MG DHHL tank in Kauluwai and pumped via an 8-inch main to DWS tanks in Kalae. DWS has two pumps at the DHHL tank. The electric driven, 40-horsepower 350 GPM turbine pump is controlled by a float switch in the upper tank of the Kalae system. An older, engine-driven, manually controlled pump provides standby capacity. Purchase cost from DHHL is $0.41 per thousand gallons. Energy cost of pumping is currently in the range of $0.45 to $0.50 per thousand gallons.

Storage and Distribution. Figure 7 illustrates the current distribution network. It began as the Meyer Kalae Ranch system and was assumed by the County in 1940. Two 47,000-gallon steel tanks and pipelines were added by the County in 1949-1953. State funds enabled the connection to the DHHL system to be made in 1970-1971. The developer of a Kalae subdivision constructed the 100,000-gallon steel tank and 8-inch distribution lines.

Water sales through the 1970's are shown in Figure 8. These increased at 3.5 percent per year, the result of a 2.2 percent increase in the number of service connections and 1.3 percent in the use rate per service connection.

Water Quality. The excellent chemical water quality is shown by annual DOH analyses on Table 4. The tunnel sources do not require turbidity measurements. Only one DOH quarterly coliform test was positive in the last two years.

Constraints. Because supply from the Meyer tunnels is limited, most increases in water demand will have to be met using more expensive water purchased from DHHL. Most of the older, 2- and 2½-inch galvanized pipelines are tuberculated and have poor hydraulic characteristics.

Halawa

Source. Sole source for the Halawa system is a diversion in Makaeleele Gulch, a tributary of Halawa Stream, at elevation 250 feet. There are other, private diversions on the stream but they are at lower elevations.

Storage and Distribution. The system is without a storage tank. Service is provided by direct diversion into the system's single, 1½-inch transmission/distribution pipeline (see Figure 9). Average water use, illustrated on Figure 10, is currently about 2000 to 2500 gpd.

Water Quality. The small size of the Halawa system does not qualify it as a "public" system according to Federal and State definitions. As such, its water is not subject to their quality standards. Quality analyses of the water were not available for this study. It is presumed that the chemical quality is excellent, turbidity is high in the rainy season, and bacterial contamination does occur occasionally.

Constraints. The remote location and small size of the system make it difficult for DWS to administer. It is maintained primarily to supply the State park in the valley. (Signs in the State park say that the water is not potable.) Were it not for this service, the system would more appropriately be owned and operated by valley residents.

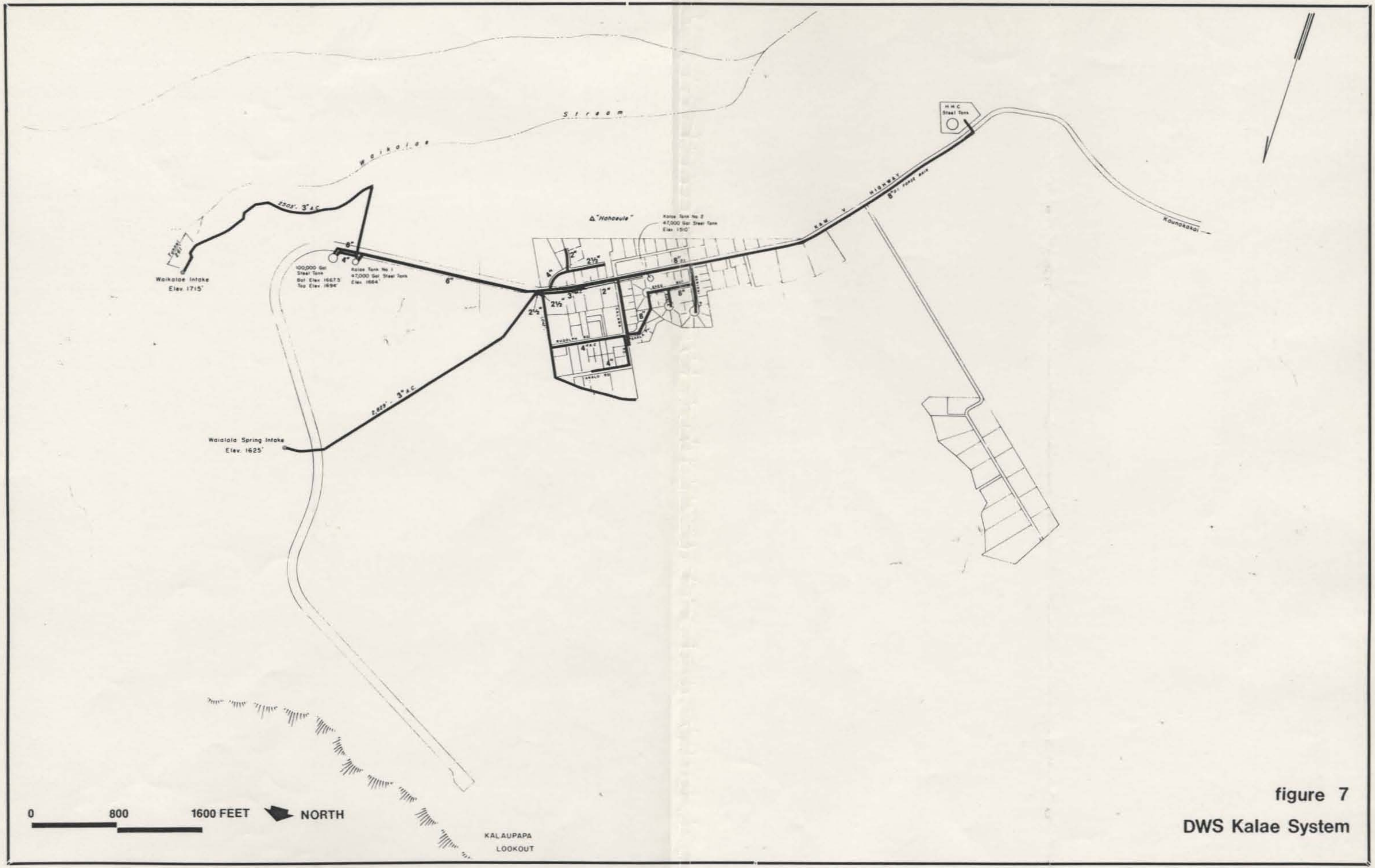
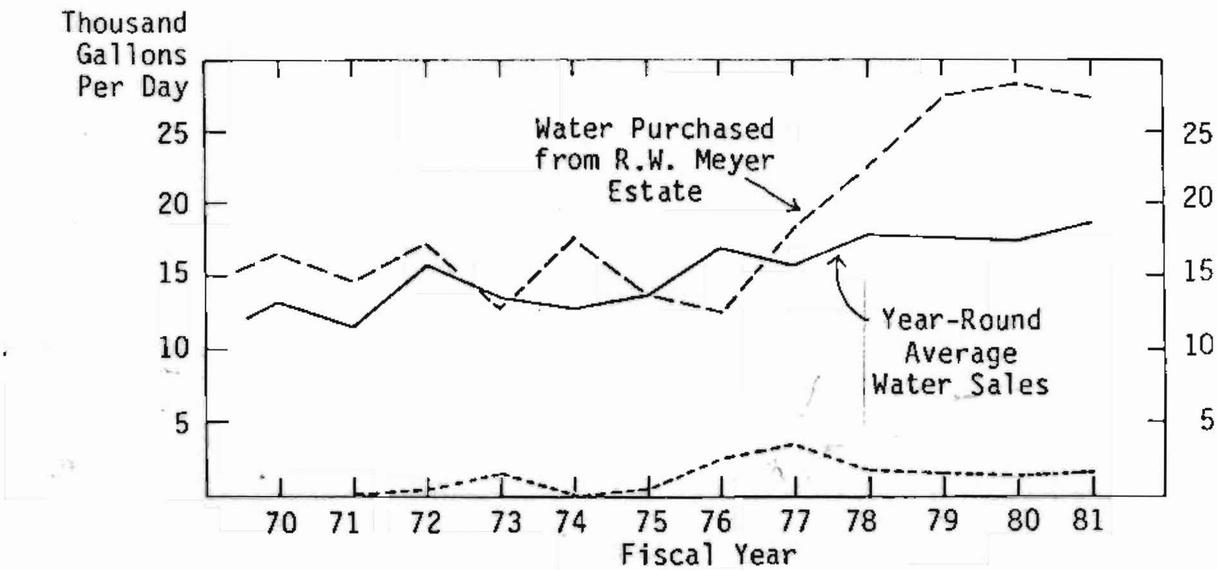
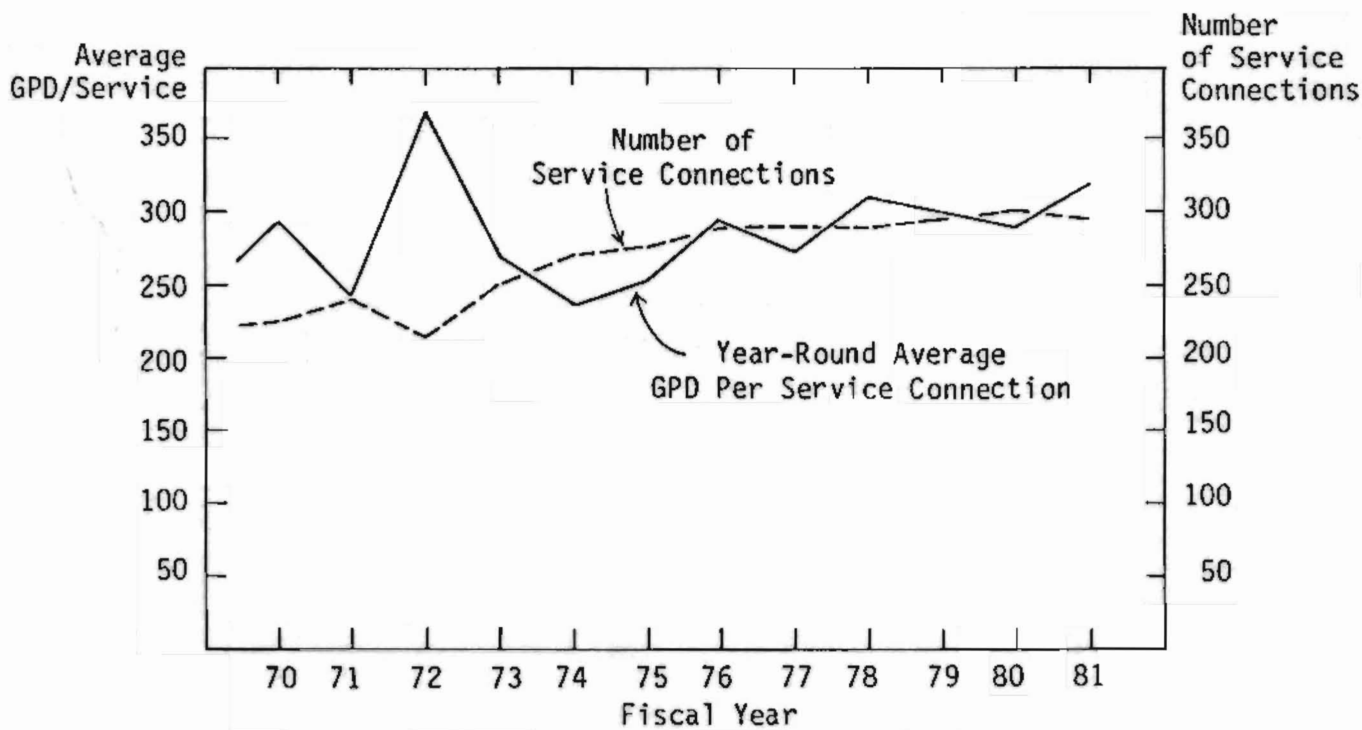


figure 7

DWS Kalae System





Source: Annual Reports of the Dept. of Water Supply

Figure 8. Kalae System Water Use in the 1970's

TABLE 4. Department of Health Chemical Analyses of the Kalae System (DOH System No. 235)

Constituent	Units	Maximum Allowable Contaminant Levels*	Date of Sample			
			12/11/78	7/24/79	9/3/80	8/17/81
Arsenic	mg/l	.05	.02	.02	.02	.02
Barium	mg/l	1	.8	.8	.8	.8
Cadmium	mg/l	.01	.005	.005	.005	.005
Chromium	mg/l	.05	.01	.01	.01	.01
Lead	mg/l	.05	.01	.02	.02	.02
Mercury	mg/l	.002	.0005	.0005	.0005	.0005
Nitrate (as N)	mg/l	10	1.4	2.1	2.97	2.44
Selenium	mg/l	.01	.01	.01	.01	.01
Silver	mg/l	.05	.03	.03	.03	.03
Flouride	mg/l	1.4	.2	.2	.2	.2
Chloride	mg/l	250**	24	23	23	24
Sodium	mg/l	none	N/A	20	15	18
Total Dissolved Solids	mg/l	500**	69	75	74	74

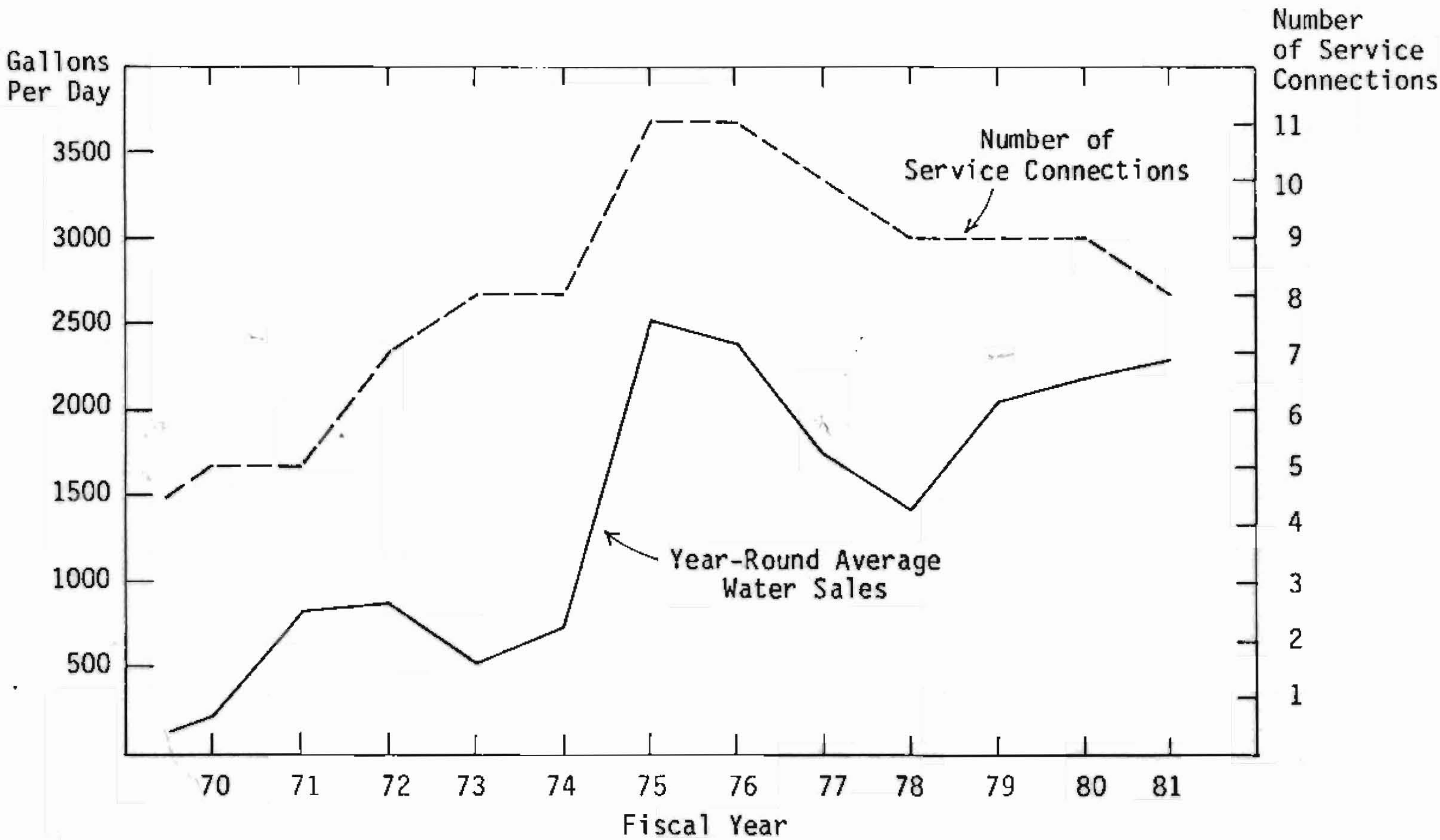
* Maximum contaminant levels are established by Federal National Interim Primary Drinking Water Standards and State Department of Health Regulations (Chapter 49).

** Secondary standards.

Source: Department of Health Drinking Water Program

figure 9

DWS Halawa System



Source: Annual Reports of the
Dept. of Water Supply

Figure 10. Halawa System Water Use in the 1970's

PRIVATE SYSTEMS

Molokai Ranch

The present Molokai Ranch system is comprised of the original Ranch system which dates from the turn of the century and the domestic system built in 1946 by Libby, McNeil & Libby to serve its plantation community in Mauna Loa. When the pineapple plantation ceased operation, responsibility for Libby's domestic system reverted to Molokai Ranch. The Ranch provides water without charge to its customers who are also its lessees. Two Ranch employees operate the system, one working with the mountain sources and the other on distribution in Mauna Loa. For other than routine operation and maintenance tasks, additional Ranch employees are utilized.

Sources. The Ranch system has six stream diversions and one tunnel in the upper Kawela, Kamoku, and Lualohi basins. There is a non-recording V-notch weir which can be used to measure total flow transmitted from the upper four stream intakes. This flow is read daily but records of it are not kept. There are no meters or flow measuring devices anywhere else in the system. A summary of the mountain sources is given in Table 5; the flow rate figures in the table are estimates only. Figure 11 is a schematic of the interconnection of these sources. Note that there is a connection to the Del Monte system which is described next in this report. Del Monte has a lease agreement for rights to one half of the water in the Ranch supply line below the Libby connection. Nominally, this amounts to a little more than one quarter of the total Ranch system supply.

The yield of the sources varies seasonally. Estimates of it have been made for this study based on conversations with Molokai Ranch personnel and the record of U.S. Geological Survey ("USGS") Gage 4150 (begun in September 1946 and terminated September 1971). The USGS gage is on East Kawela gulch just downstream of the Ranch diversion. Zero flow at the gage, which means that the Ranch diversion has captured all of the stream's flow, occurred 38 percent of time during the 25-year record. The corollary to this is that 62 percent of the time, the diversion pipeline was full and water flowed past its intake to the USGS gage. This suggests that the system's maximum yield occurs a little over 60 percent of the time.

Minimum flow from all sources is probably about 110,000 GPD. This is based on the minimum flow at the weir observed by Ranch personnel of about 80,000 GPD and estimated flow from Lualohi tunnel below the weir of 30,000 GPD. Supply in the 120,000 to 135,000 GPD range occurs in the late summer-early fall of most years. The various storage reservoirs, a total of 10 MGD in Lualohi and another 8 MGD in Puu Nana-Mauna Loa, can augment low source flow. If carefully managed, dry season yield is estimated to be 0.3 MGD.

Storage and Distribution. Figures 12 and 13 illustrate the 20-mile long Ranch system from mountain diversion to distribution in Mauna Loa. (The Ranch's irrigation and stock water pipelines in Mauna Loa have not been shown on either of these drawings.) The original transmission line to Mauna Loa was a 2½-inch pipeline constructed in 1912. The system has been added to incrementally a number of times since. The last major additions were the 6- and 8-inch pipeline from Poholua tank to Puu Nana in 1959, the 5-MG, asphalt fiber-lined open reservoir in Puu Nana in 1960, and the 5-MG, asphalt fiber-

TABLE 5. Summary of Molokai Ranch System Sources

Source	Elevation at Intake (Feet)	Drainage Area (Square Miles)	Flowrate Approximations: Minimum Flow (MGD)	Flowrate Approximations: Maximum Divertable Flow (MGD)
Sources above Libby Connection				
East Kawela Gulch (2 intakes)	3625 and 3775	0.52	0.05	0.50
West Kawela Gulch	3675	0.086	0.00	0.10
Kamoku Gulch	3675	0.13	0.015	0.15
Ohialele Gulch	3775	0.11	0.015	0.15
Sources below Libby Connection				
Lualohi Tunnel	2550	(1000-ft. tunnel)	0.03	0.05
Lualohi Gulch	2300	0.23	0.00	0.10
Kalihi Gulch	2320	0.10	0.00	0.07
Total Supply			0.11	0.7 to 0.8*

* Maximum supply of sources above the Libby connection is limited by transmission pipeline capacity to approximately 0.55 MGD. This is added to the 0.2 MGD maximum from the sources below to arrive at the 0.7 to 0.8 MGD estimated total.

Notes:

1. Most pipelines are above ground or only partially buried.
2. Pipelines above the Del Monte connection are transite. The Ranch is replacing the 6-inch pipe above the 5 MG open reservoir with 8-inch PVC.
3. The 1 MG Poholua tank was built in 1931; the 4 MG Libby tank in 1946; and the 5 MG open reservoir in the late 1960's.
4. The original source was Lualohi Tunnel drilled in 1900. Diversion at Ohialele Gulch was added in 1917 and extension to East Kawela in 1923. The East Kawela pipe and stream diversion was replaced in 1935.

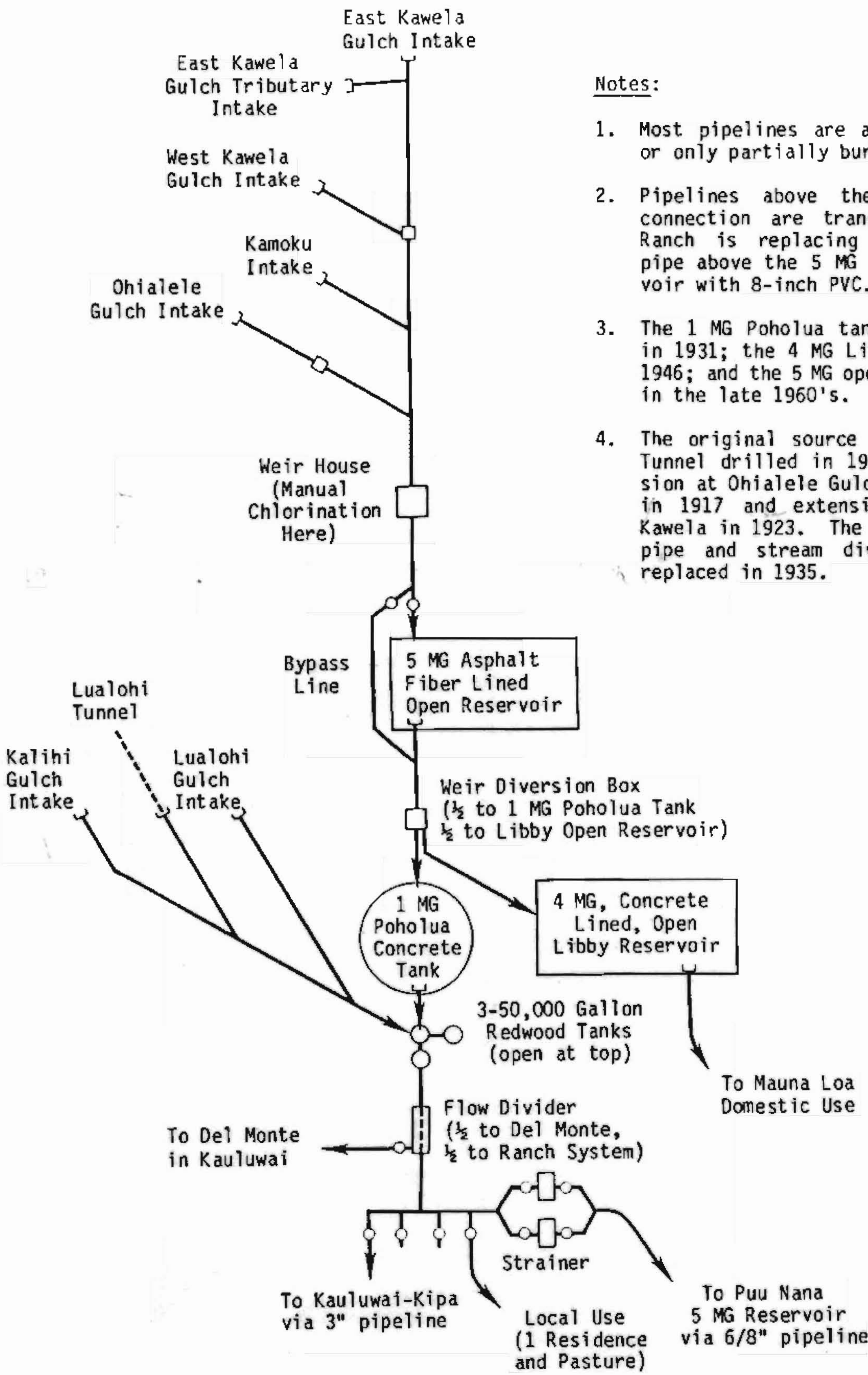


figure 11

Schematic of the Molokai Ranch System's Mountain Sources

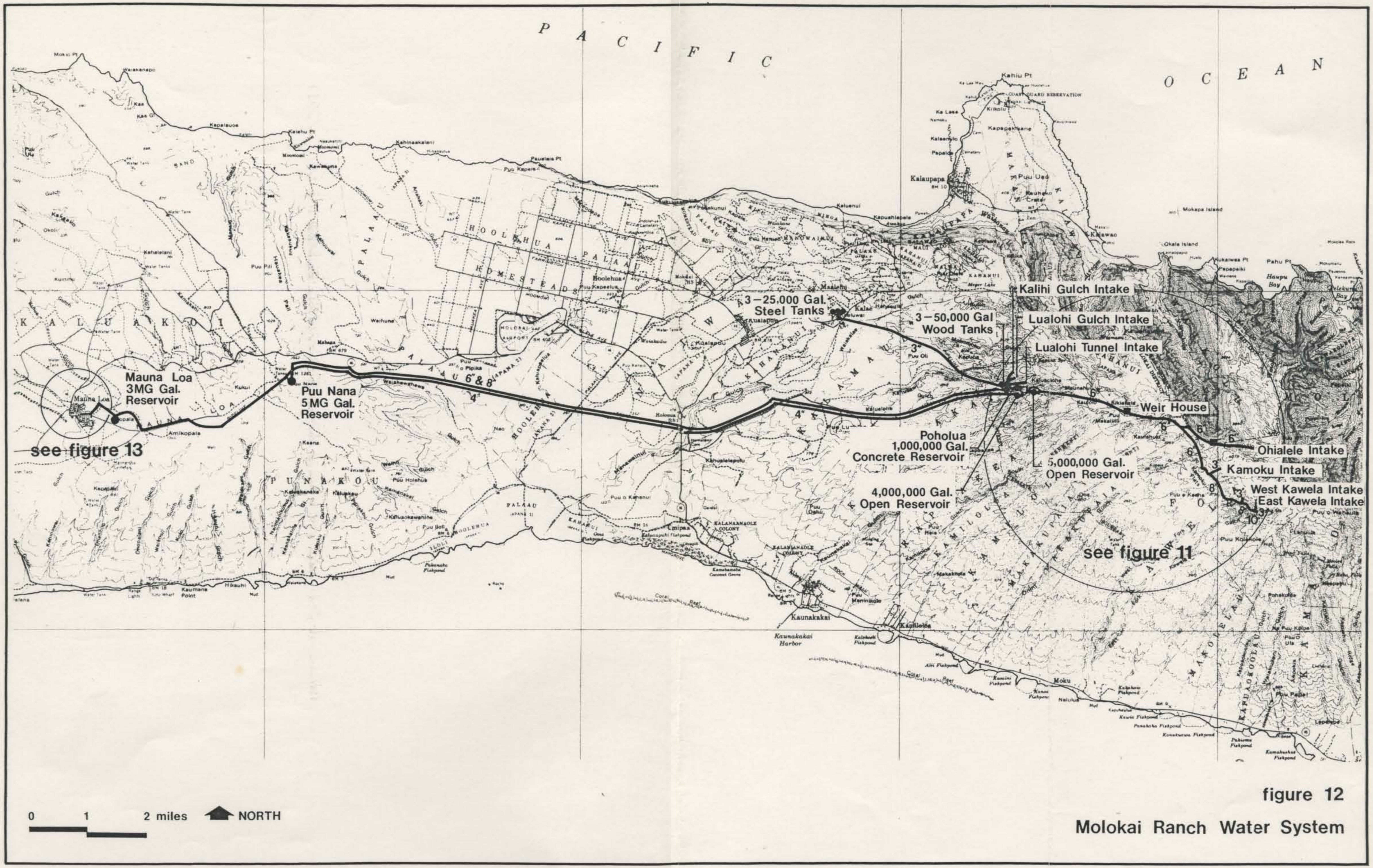


figure 12

Molokai Ranch Water System

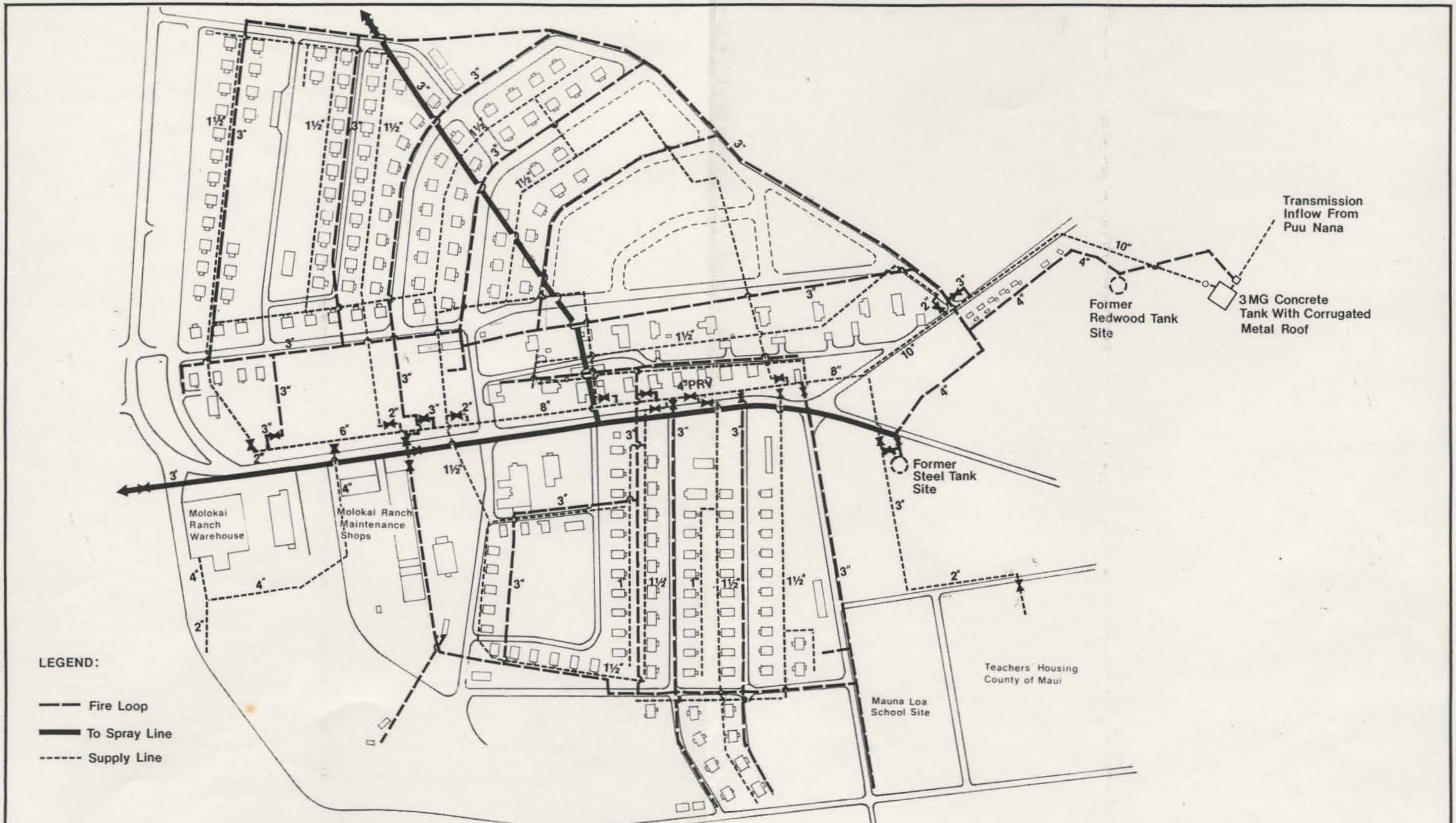


figure 13

Molokai Ranch Distribution Network in Mauna Loa

lined open reservoir in Lualohi in the late 1960's. The Ranch system flows entirely by gravity from mountain sources to all users. Other than gate valves, control of flow at the downstream end of the system has never been installed. Due to the age of pipes and very high pressures in the transmission pipeline, flow control is done manually from the upper end of the system.

Domestic users of the system are summarized by service area below. In addition to this use, agriculture and livestock water used by the Ranch is taken from the Puu Nana reservoir in a pipeline system which is separate from domestic distribution in Mauna Loa. As use rates are not metered, they can only be estimated. By service area, average domestic use is estimated to be 75,000 GPD in Mauna Loa, 15,000 GPD in Kipu, and 10,000 GPD in lower Manawainui.

Summary of Domestic Users of the Molokai Ranch System

Mauna Loa
- 206 residences
- 6 small commercial establishments
- Mauna Loa Elementary School
- Recreation Center
- Park and Athletic Field
- Church
- Ranch offices, haybailing, and maintenance yard

Kipu
- 21 residences

Lower Maunawainui
- 6 residences
- 2 commercial services (Pacific Concrete & Rock Company and Friendly Isle Construction)

Water Quality. There is no treatment of Ranch system water except for chlorination. Pittchlor is added manually in the weir box in Lualohi and also in the 3 MG concrete tank above Mauna Loa. A gas chlorinator has been recently installed in Mauna Loa which will replace manual chlorination there. As a surface water system without coagulation-filtration, turbidity above State DOH standards occurs during rainy periods (refer back to Table 2). Bacterial standards have been exceeded on virtually every quarterly check by DOH. This is probably due to the condition of distribution pipelines in Mauna Loa. However, as the DOH analyses on Table 6 show, chemical quality of the Ranch's mountain water is excellent.

Constraints. As a system with no pumping or treatment, the Ranch system yields very inexpensive water. However, continuing domestic service is proving to be a three-fold liability. First, State and Federal drinking water standards cannot be met without installing treatment facilities. At present, the Ranch does not have plans to do this. Second, distribution pipes in Mauna Loa are badly turberculated and require almost daily remedial work. Extensive replacement is warranted. Third, domestic use reduces the amount of water available for agricultural use. In the late summer-early fall, domestic use consumes virtually all available water. An interconnection with the Kalua Koi system augments the supply required for both domestic and agricultural use during low flow periods.

TABLE 6. Department of Health Chemical Analyses of the Molokai Ranch System (DOH System No. 231)

Constituent	Units	Maximum Allowable Contaminant Levels*	Date of Sample 12/11/78	7/24/79	7/22/80	9/28/81
Arsenic	mg/l	.05	.02	.02	.02	.07
Barium	mg/l	1	.8	.8	.8	.8
Cadmium	mg/l	.01	.005	.005	.005	.005
Chromium	mg/l	.05	.01	.01	.01	.01
Lead	mg/l	.05	.01	.02	.01	.02
Mercury	mg/l	.002	.0005	.0005	.0005	.0005
Nitrate (as N)	mg/l	10	.05	.15	.13	.20
Selenium	mg/l	.01	.01	.01	.01	.01
Silver	mg/l	.05	.03	.03	.03	.03
Flouride	mg/l	1.4	.2	.22	.2	.2
Chloride	mg/l	250**	26	18	11	14
Sodium	mg/l	none	N/A	8.2	6.8	9
Total Dissolved Solids	mg/l	500**	79	80	60	81

* Maximum contaminant levels are established by Federal National Interim Primary Drinking Water Standards and State Department of Health Regulations (Chapter 49).

** Secondary standards.

Source: Department of Health Drinking Water Program

Del Monte

Del Monte operates a domestic system for its offices, maintenance yard, and residential community in Kualapuu. Water service is provided without charge. It assigns two of its plumbers to work two or three hours a day to operate and maintain the system.

Sources. The system's primary source is mountain (surface) water obtained from the Molokai Ranch system through a lease agreement. It enables Del Monte to receive one quarter of the Ranch's mountain supply via a 3-inch steel and galvanized iron pipeline from Luolohi to Del Monte's 1.0 MG tank in Kauluwai. By the configuration of pipelines and tanks of the Ranch's system (shown schematically on Figure 11), Del Monte actually receives somewhat more than one quarter. For one half to two thirds of the year, Del Monte's share probably could amount to 135,000 to 150,000 GPD. In late summer and early fall, this source may drop to as low as 35,000 to 40,000 GPD. These are estimates as no measurements of the supply amount are made.

The second source of the system, utilized on an as needed basis, is the State's MIS water. Del Monte has a 12-inch irrigation connection on the State's transmission pipeline east of Kualapuu. Its primary purpose is irrigation of pineapple fields there. However, a pump and pipeline can deliver a portion of this water to Del Monte's domestic tanks and treatment facilities above Kualapuu when the supply from the Molokai Ranch system is insufficient. The State meters water supplied to Del Monte at the 12-inch pipeline connection, but the portion taken for domestic use is not measured.

Storage and Distribution. Del Monte's domestic system has three tanks and a total storage of 1.3 million gallons. A 1.0 MG steel tank, built in 1941 at elevation 1450 feet in Kauluwai, receives water from the Molokai Ranch mountain source (see Figure 14). There is a 6-inch pipeline between this tank and the 50,000 and 250,000 gallon concrete tanks at 980 feet above Kualapuu. These also receive water pumped from the State MIS. Plans of distribution pipelines within Kualapuu were not available. It is known that the pipelines are relatively old steel and galvanized iron. Uses served by the system are:

- Del Monte office complex
- Equipment storage and maintenance yard
- 120 employee residences
- 2 men's barracks (about 15 individuals total)

Water Quality. Raw water is chlorinated by a gas chlorinator before entering the two lower tanks. Eight pressure sand filters with a total capacity of 200 GPM are located on the main distribution pipeline from these tanks. These clarify water at the varying rate of flow in the distribution line. Chemical quality of the water is excellent (see Table 7), no incidences of high turbidity have been reported to DOH (refer back to Table 2), and there has been only one positive coliform count in quarterly analyses performed by DOH over the last three years.

Constraints. Except for occasional blow-outs of the mountain supply pipeline and the usual maintenance required for older distribution pipelines, Del Monte reports no problems with its system. Recent investment in the filters has brought the water into compliance with State drinking water standards. Operation of the system does not increase Del Monte's overall manpower requirements.

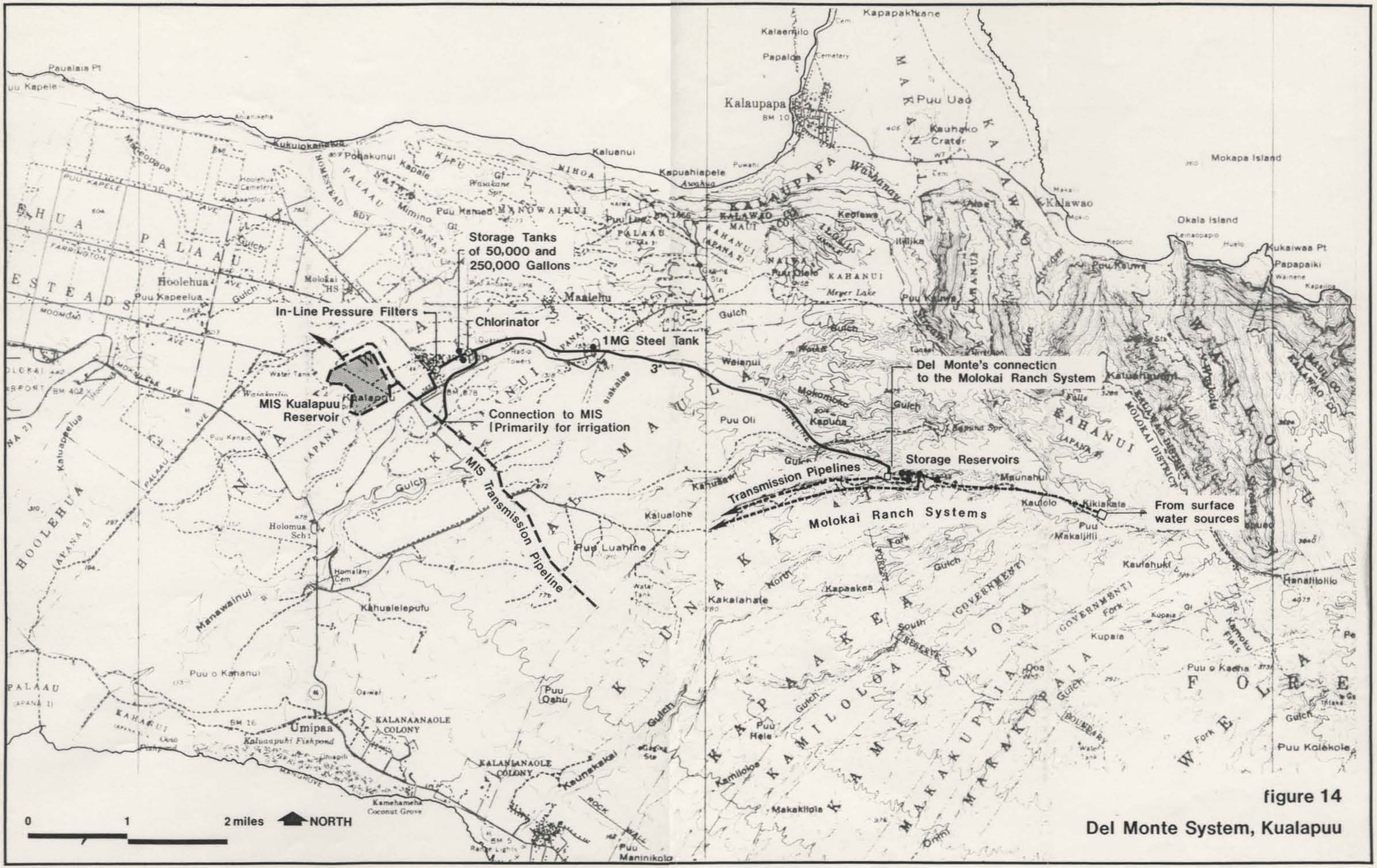


figure 14

Del Monte System, Kualapuu

TABLE 7. Department of Health Chemical Analyses of the Del Monte System (DOH System No. 229)

Constituent	Units	Maximum Allowable Contaminant Levels*	Date of Sample			
			12/11/78	7/24/79	7/22/80	9/28/81
Arsenic	mg/l	.05	.02	.02	.02	.02
Barium	mg/l	1	.8	.8	.8	.8
Cadmium	mg/l	.01	.005	.005	.005	.005
Chromium	mg/l	.05	.01	.01	.01	.01
Lead	mg/l	.05	.01	.02	.01	.02
Mercury	mg/l	.002	.0005	.0005	.0005	.0005
Nitrate (as N)	mg/l	10	.05	.35	.30	.36
Selenium	mg/l	.01	.01	.01	.01	.01
Silver	mg/l	.05	.03	.03	.03	.03
Flouride	mg/l	1.4	.2	.2	.2	.2
Chloride	mg/l	250**	22	14	22	24
Sodium	mg/l	none	N/A	8.9	9.3	13
Total Dissolved Solids	mg/l	500**	73	73	86	128

* Maximum contaminant levels are established by Federal National Interim Primary Drinking Water Standards and State Department of Health Regulations (Chapter 49).

** Secondary standards.

Source: Department of Health Drinking Water Program

Kalua Koi

The Kalua Koi system began operation in June 1976. On November 1981, it became Molokai Public Utilities, Inc., a wholly owned subsidiary of Kalua Koi Corporation and a public utility subject to Public Utilities Commission regulation. Ten of Kalua Koi's employees are involved in operating the water system but all have responsibilities for roads, landscaping, and the sewerage system of the resort as well. On the average, each spends one third of his time involved in the operation of the water system. Pacific Electro-Mechanical, Inc. has a maintenance contract for Kalua Koi pumps and mechanical equipment. About $350 per month of it is attributable to water system equipment. Water is sold at $1.35 per thousand gallons plus nominal meter and fire protection charges.

Source. Kalua Koi owns and pumps water from Well 0901-01, formerly known as Well 17. It was drilled in 1951 by Del Monte for irrigation use. Del Monte stopped using the well when less expensive MIS water became available in the late 1960's. Kalua Koi purchased the well in 1975, replaced its submersible pump with a diesel-driven line shaft turbine pump, and began pumping in June 1976. Pertinent data of the well and pump are:

Identifying Numbers(s): 0901-01; Well 17

Elevation at top of casing: 982.3 ft.

Depths: 969 ft. of solid casing (to +13 ft.); 32 ft. of screened casing (to -19 ft.); 68 ft. of open hole (to -87 ft.)

Diameters: 24-inch drill hole; 18-inch casing

Pump: 1750 GPM Layne line shaft turbine

Drive: 600 horsepower diesel with right angle drive

A July 11, 1975 rental agreement with the State Department of Land and Natural Resources ("DLNR"), Division of Water and Land Development ("DOWALD") enables Kalua Koi to transmit water through the MIS. Kalua Koi pumps water into the MIS transmission pipeline east of Kualapuu. It takes out the amount it has pumped in, less 10 percent at Mahana. From Mahana, Kalua Koi pumps the water through its 10,400 ft. long, 24-inch pipeline to open, butyl-lined reservoirs of 1 and 3.5 MG at Puu Nana. Pump capacities at Mahana are 2400 and 900 GPM, each driven by an electric motor. The pumps and 24-inch pipeline had been installed by Dole for pineapple irrigation and were purchased by Kalua Koi.

MIS transmission rental is $45,000 annually for the first 10 years and will be renegotiated for the two 5-year periods following. Maximum daily withdrawal at Mahana is limited to 2 MG and it requires an input from the well of 2.22 MGD. Actual transmission has averaged 0.54 MGD in the first five years, although daily amounts have frequently been greater than 1 MGD.

Storage and Distribution. Kalua Koi has three storage tanks, the open reservoirs at 1400 ft. at Puu Nana and a 2 MG concrete (enclosed) tank at 550 ft. along the Resort's entrance road (see Figure 15). Transmission from the Puu Nana reservoirs is via 17,000 ft. of 24-inch and 16-inch pipeline to the intersection of the Resort's entrance road and Mauna Loa Highway, and from there via 14,000 ft. of 12-inch pipeline along the entrance road to the 2 MG tank at elevation 550 ft. There is a 10,000-gallon pressure breaker tank along the entrance road at elevation 990 ft. Also, there are several cross connections with the Molokai Ranch system. These are above Mauna Loa Highway and were made by Dole. One is at the Ranch's 5 MG open reservoir at Puu Nana and another is at a Dole irrigation standpipe near the Mauna Loa golf course. Others are thought to exist but were not located during the course of this study. Intermittent use of water by the Ranch is not metered.

The distribution pipeline from the 2 MG concrete tank is a 9400 ft. long, 20-inch pipeline within the Resort's access road R.O.W. There are branching 16-inch pipelines in the roads connected to the main access road. There is also a smaller, higher level distribution system which serves the 34-lot Moana Makani agricultural subdivision located along the Resort's access road. This system taps into the transmission pipeline just before the pressure breaker tank at elevation 990 ft. It consists of 15,000 ft. of 6-inch pipeline within the access road right-of-way.

At present, the Resort's golf course has been the largest water user. It has averaged about 0.40 to 0.45 MGD but uses as much as 0.75 MGD in late summer and early fall. Water sales to other customers are shown in Figure 16. The 292-room Sheraton Hotel has averaged 130,000 to 150,000 GPD in its first five years. Construction of Paniolo Hale and Ke Nani Kai condominiums added substantially to water sales in 1981.

Water Quality. Water received by Kalua Koi at Mahana is surface water of the MIS which has high turbidity in rainy periods. Kalua Koi has a two-step treatment process. Nalcolyte 8102, a coagulating agent, is injected at the pressure breaker tank. At the 2 MG concrete tank, water from the 12-inch transmission line goes through either of the two identical, 20-ft. diameter, Permutit automatic valveless gravity sand filters. Filtered water is (gas) chlorinated prior to delivery into the 2 MG tank. Filtration alone had proven unable to reduce rainy season turbidity to less than the 1 TU required by DOH standards. The Nalco coagulant was recently added and has proven to be successful. Table 8 summarizes annual chemical analyses done by the State DOH. All constituent concentrations are well below allowable contaminant levels.

Constraints. Two major pumping lifts and payment of transmission rental make Kalua Koi water expensive. Current operating costs are estimated to be $1.45 per 1000 gallons. This does not include capital or replacement costs.

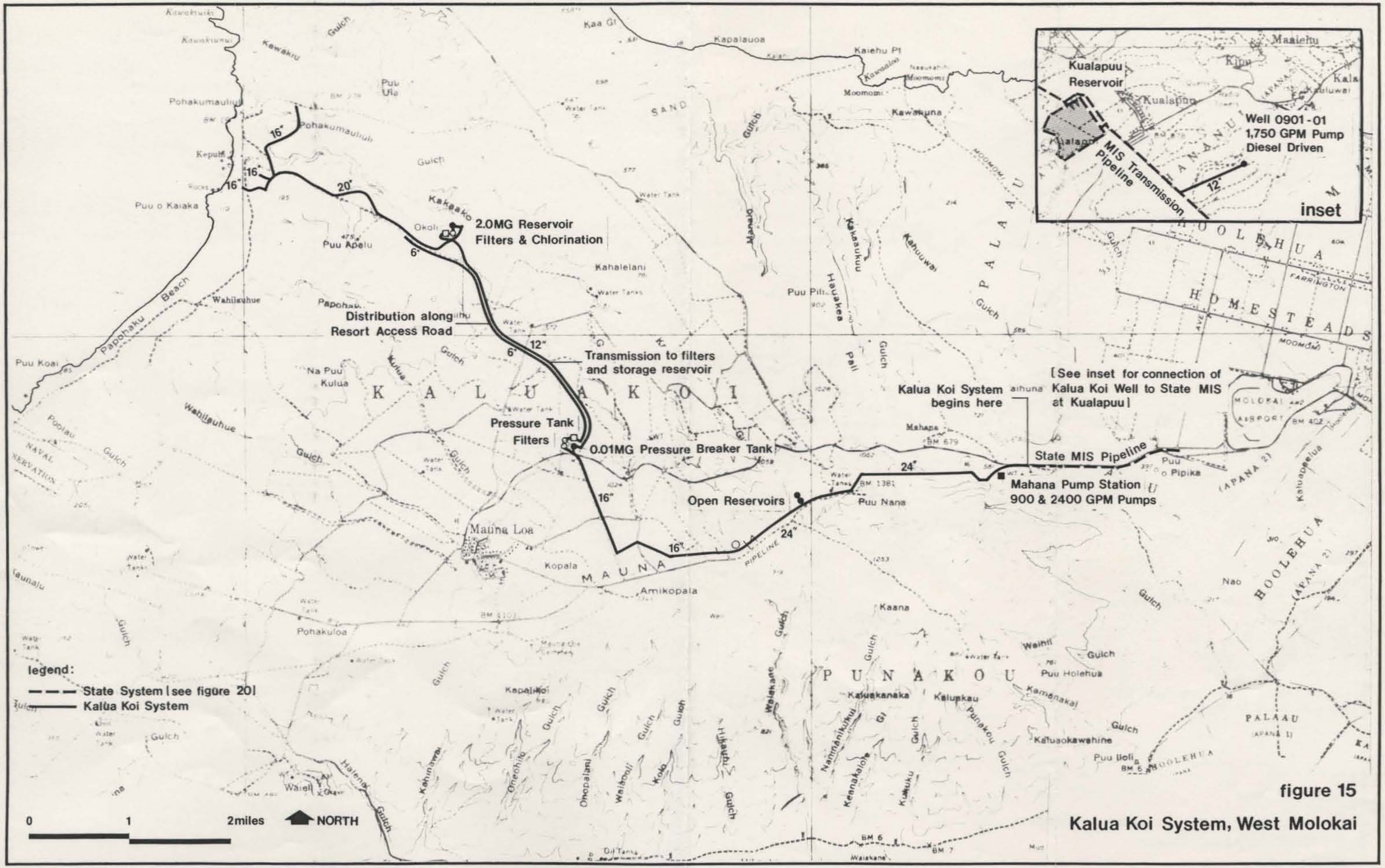
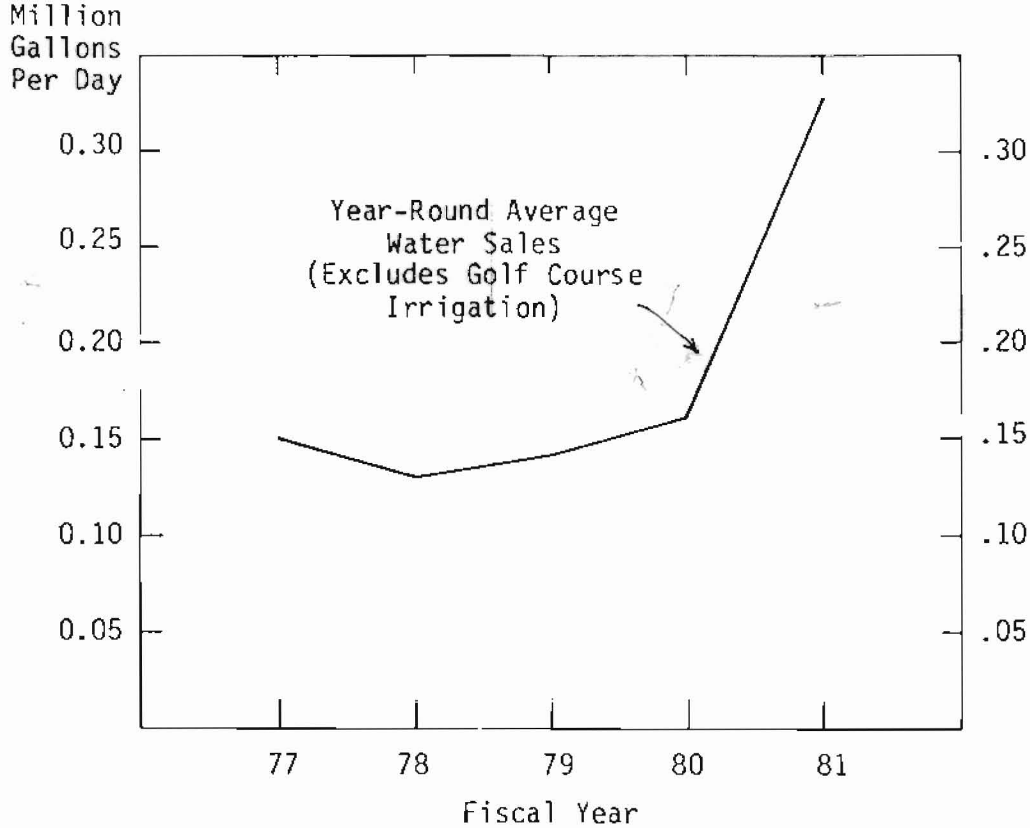


figure 15

Kalua Koi System, West Molokai



Source: Files of Kalua Koi
Corporation

Figure 16. Kalua Koi System Water Use, 1977 to 1981

TABLE 8. Department of Health Chemical Analyses of the Kalua Koi System (DOH System No. 236)

Constituent	Units	Maximum Allowable Contaminant Levels*	Date of Sample 10/29/79	7/22/80	9/28/81
Arsenic	mg/l	.05	.02	.02	.02
Barium	mg/l	1	.8	.8	.8
Cadmium	mg/l	.01	.005	.005	.005
Chromium	mg/l	.05	.01	.01	.01
Lead	mg/l	.05	.02	.01	.02
Mercury	mg/l	.002	.0005	.0005	.0005
Nitrate (as N)	mg/l	10	.20	.23	.29
Selenium	mg/l	.01	.01	.01	.01
Silver	mg/l	.05	.03	.03	.03
Flouride	mg/l	1.4	.2	.2	.2
Chloride	mg/l	250**	23	19	20
Sodium	mg/l	none	12	9.3	11
Total Dissolved Solids	mg/l	500**	105	83	102

* Maximum contaminant levels are established by Federal National Interim Primary Drinking Water Standards and State Department of Health Regulations (Chapter 49).

** Secondary standards.

Source: Department of Health Drinking Water Program

Operating Cost Item	Estimated Cost (Dollars/Thousand Gallons)	Comment
Well 0901-01 Pumpage	$0.46	Based on diesel fuel and 10% overpumpage
Transmission Rental	0.12	Based on current potable and golf course supply
Mahana Pumpage	0.70	Assumes 610 ft. pumping head and electric motor-driven pumps on Schedule "P" Molokai Electric Service
Maintenance contract	0.02	Based on $350 per month and the current pumpage rate
Kalua Koi Manpower and Miscellaneous	0.15	Estimated by Kalua Koi Corporation
Total of Operating Costs	$1.45	

A larger question for the Resort than the cost of its water is the 2 MGD transmission limit through the MIS established by contract. Other elements of Kalua Koi's source-transmission-distribution facilities have existing or potential capacities substantially in excess of 2 MGD. If the Resort is to develop as it is planned, 2 MGD will not be a sufficient supply. Projected water use and supply requirements are presented in the next section of the report.

Kawela Plantation

Kawela Plantation is a 210-lot agricultural subdivision project. Lots are typically two acres in size. The project has three, physically separate increments, all of which are presently under construction. As a condition of County approval, sufficient water for agriculture and domestic use must be provided. The developer is building separate agriculture and domestic systems, both of which will remain private. Each is described here to the extent that information is available.

Sources. For the domestic water system, three 6-inch cased wells have been completed just east of Kawela Gulch. All are located at about 230 feet elevation and spacing between them is approximately 1500 feet. (DWS' Conant-Kawela well is in Kawela Gulch, 1600 feet from the nearest 6-inch well.) Pumpage from the new wells will be by line shaft turbines at 75 GPM: the design calls for a combined supply of 210,000 GPD, providing up to 1000 GPD per lot. Well water will be delivered via 3- and 4-inch transmission pipelines to a nearby 0.1 MG reservoir; it will not be pumped directly into the distribution network.

The irrigation supply, also designed to provide up to 210,000 GPD, has two sources. Most pumpage will be from well 0456-04, a vertical shaft and horizontal skimming tunnel constructed in 1921. (This well is also known as

Shaft 5, Breadfruit-tree.) It is located on the east side of Kawela Gulch along the entrance road to Unit I of the project. The second source is a 6-inch well drilled by the developer on the west side of Kawela Gulch. It is known to yield brackish water but no other information was available for this study.

Storage and Distribution. The domestic system has two pressure zones, the upper one fed from tanks of 0.15 and 0.20 MG at elevation 535 feet and the lower one fed from two 0.1 MG tanks at 235.5 feet (see Figure 17). Water from the supply wells is pumped into the 0.1 MG tank on the east side of the project. Float switches in the two upper tanks activate booster pumps at the respective lower tanks to supply the upper pressure zone. All distribution pipelines are 8-inch; all are in road R.O.W.'s except for pipeline links between the project's increments.

The irrigation system design is based on a 10 GPM delivery rate to individual houselots and scheduled use which would limit the number of lots supplied simultaneously. These restrictions will provide adequate flow and pressure for drip irrigation; storage and booster pumping by lot owners would be required for sprinkler irrigation. The criteria enable transmission lines of two and three inches in size and storage tanks of 10,000 gallons in each increment of the project. Plans of the distribution piping were not available for the study, but presumably pipes are within road right-of-ways to serve all lots.

Water Quality. Chemical analyses of the well sources were not available for the study. The developer is expected to submit quality data to DOH to certify his well sources in the near future. In general, quality should be similar to DWS' nearby Conant-Kawela well source. It is known that the cadmium level in one of the three domestic wells exceeds DOH's maximum allowable level. For this reason, all well water is transmitted to the same 0.1 MG tank for batching rather than pumped directly into distribution pipelines. The cadmium content of aggregate well water is within allowable concentrations (S.P. Bowles, personal communication).

Constraints. Both water systems have been installed and are now supplying water for construction and the project nursery. Of some concern is the proximity of its supply wells to the County's Conant-Kawela well. As noted in the description of the Kaunakakai system, the regional yield of potable quality water is limited. Anticipated pumpage by Kawela Plantation limits DWS' option to increase pumpage at its Conant-Kawela well.

STATE SYSTEMS

Department of Hawaiian Home Lands (DHHL)

The DHHL water system began operation in 1922. A small dam built by Molokai Ranch at Waihii Spring was the original source of supply and a pipeline to the Kalamaula colonies was constructed. The DHHL system is now quite extensive and is in the middle of a five- to seven-year capital improvements program which will eventually upgrade most of its facilities. Operation, maintenance, and meter reading are done by three employees working full time. Pumps are maintained through a maintenance contract with Pacific Electro-Mechanical, Inc. Administrative tasks are handled by the DHHL office staff in Hoolehua. Water is sold to all customers for $0.41 per thousand gallons.

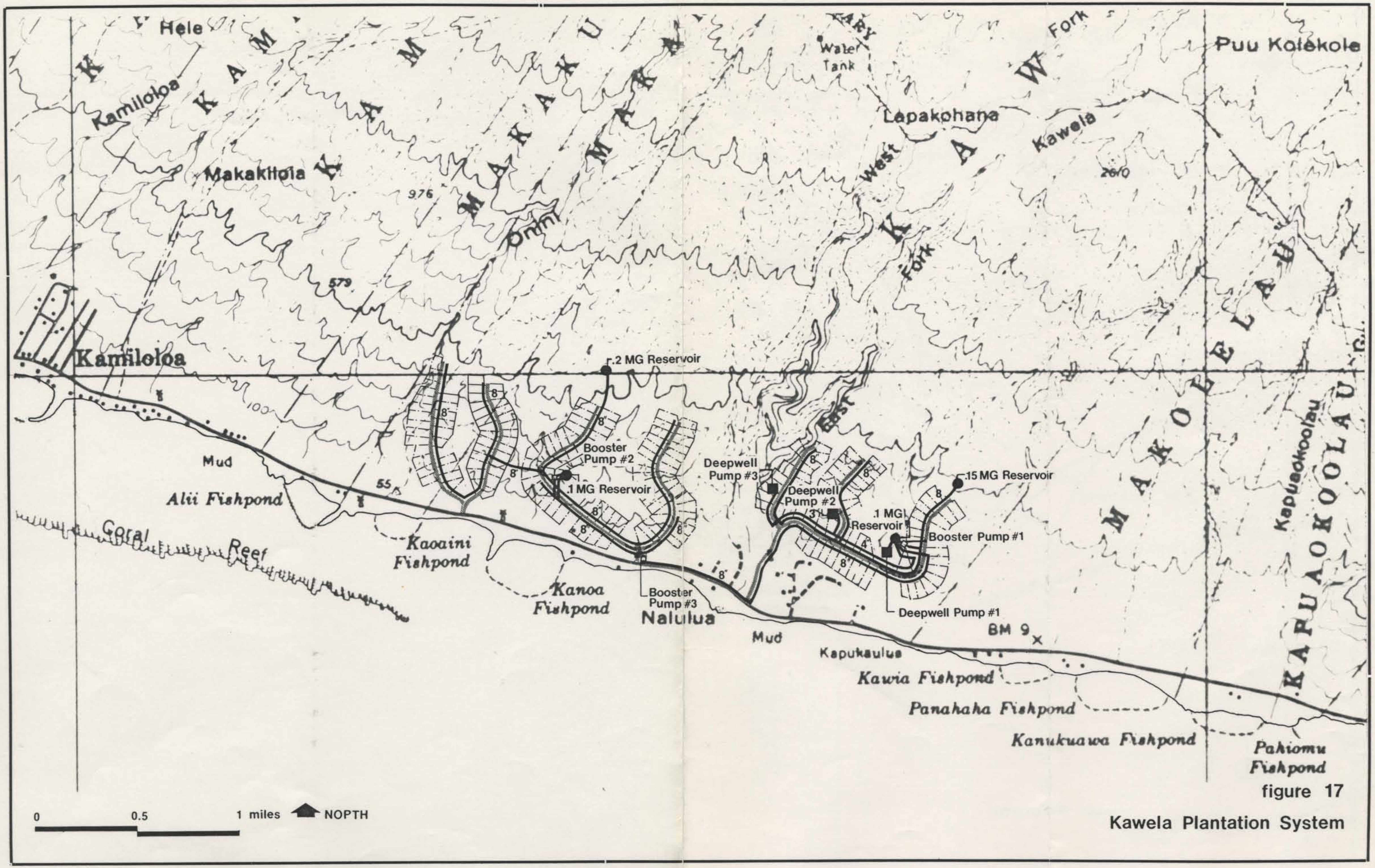


figure 17

Kawela Plantation System

Sources. There are two surface water sources and two deep wells. The surface sources date from the 1920's. An intake on Waihanau Stream at elevation 2260 feet, a 2800 ft. long tunnel, and a 17,000 ft. long transmission pipeline were constructed from 1924 to 1926. Its yield varies seasonally from an 800,000 GPD average in rainy months to as low as 3,000 GPD in dry July to September months. Capacity of the transmission pipeline is approximately 1.3 MGD. The other surface source is an intake on Kamiloloa Gulch at 3100 ft. Yield averages 15,000 to 20,000 GPD with substantial seasonal fluctuation. Its 3- and 4-inch transmission pipeline was completed in 1927. Both surface sources deliver water for filtration and storage at elevation 1410 ft. in Kauluwai. The filters, which were installed recently, have a capacity of 0.5 MGD. Inflow greater than this now overflows to waste.

The two deep wells are adjacent to each other at elevation 1005 feet along the pipeline from Kauluwai to Kalamaula. The first well, commonly known as Well 16, was drilled in 1948 and put into service in 1953. The second was drilled in 1979 and only recently put into service. Pumping cost limits their use to an as needed basis. Pumping into the adjacent head tank, the electrical cost is estimated to be $0.94 per thousand gallons. If booster pumping up to the Kauluwai tank to serve the Hoolehua area is required, the added electrical cost is approximately $0.41 per thousand gallons. Available data on the wells and pumps are as follows:

USGS Well Number	0801-01	0801-02
Date Drilled	1948	1979
Ground Elevation	1005	1005
Total Depth (ft.)	1095	1092
Solid casing length (ft.)	1009	
Perforated casing length (ft.)	68	
Open hole below the casing (ft.)	18	
Casing diameter (inches)	14	14
Nominal capacity of the installed pump (GPM)	425 (submersible)	750 (line shaft turbine)

Storage and Distribution. Storage tanks in the system are: the 1.0 MG concrete tank at elevation 1412 feet in Kauluwai; two identical 3.5 MG concrete tanks built in 1934 above the Hoolehua service area at elevation 1020 ft.; and a 0.1 MG concrete tank next to the wells built in 1980-81 (refer to Figure 18 for the locations). Construction of a 0.2 MG distribution tank at elevation 233 feet above Kalamaula will begin sometime this year.

From the 1.0 MG tank in Kauluwai, distribution to the Kalamaula colonies is by an 8-inch cast iron pipeline down to the site of the wells, and then by a 4- and 3-inch cast iron pipe down to the coast. Within the colonies, distribution is by a network of 1- to 3-inch galvanized pipes. Along with the 0.2 MG tank mentioned above, work on a 12-inch pipeline from the wells to this tank to replace the 3- and 4-inch pipe will begin this year. The next phase of DHHL's CIP will replace the galvanized pipelines in Kalamaula with distribution mains built to DWS standards. The distribution network in Hoolehua, fed from the two 3.5 MG concrete tanks, is comprised of older, small diameter galvanized pipelines and more recently installed 6- and 8-inch cast iron mains. DHHL's last CIP phase is intended to bring all of this network up to DWS standards.

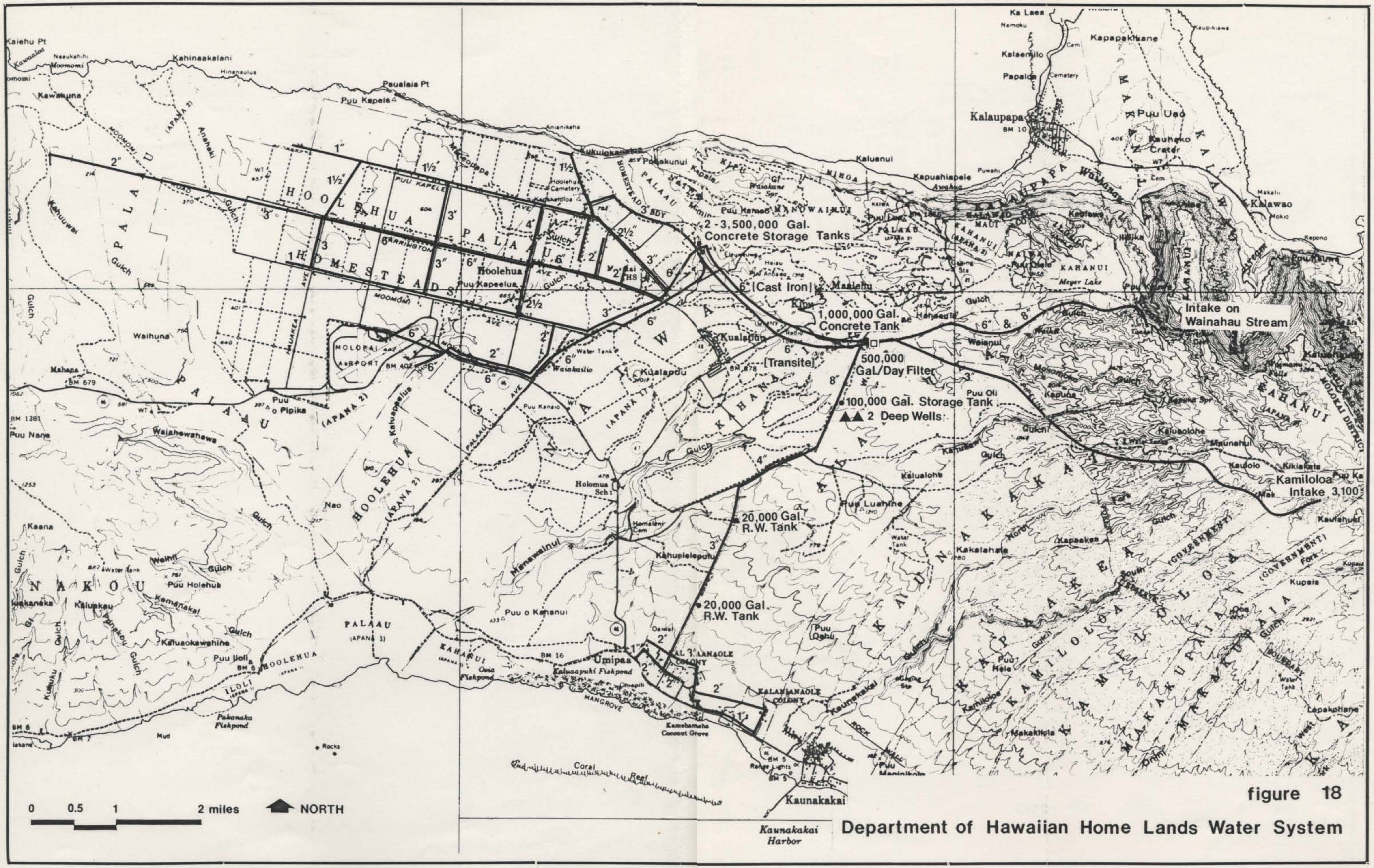


figure 18

Department of Hawaiian Home Lands Water System

Locations and numbers of metered customers are tabulated below. Service to other than DHHL homesteaders is substantial. DWS and the Federal Aviation Administration have pumps at the Kauluwai tank site which deliver purchased DHHL water to users at higher elevations. Molokai Ranch has recently installed a pump at this site and will soon purchase DHHL water to supply its 21 residential customers in Kipu. In the Hoolehua area, non-homesteader customers with significant water use include Kualapuu Elementary School, Molokai Intermediate and High School, Molokai Airport, and various lessees at the airport. Non-homesteader customers in Kalamaula use water on a relatively small scale compared to Kauluwai and Hoolehua.

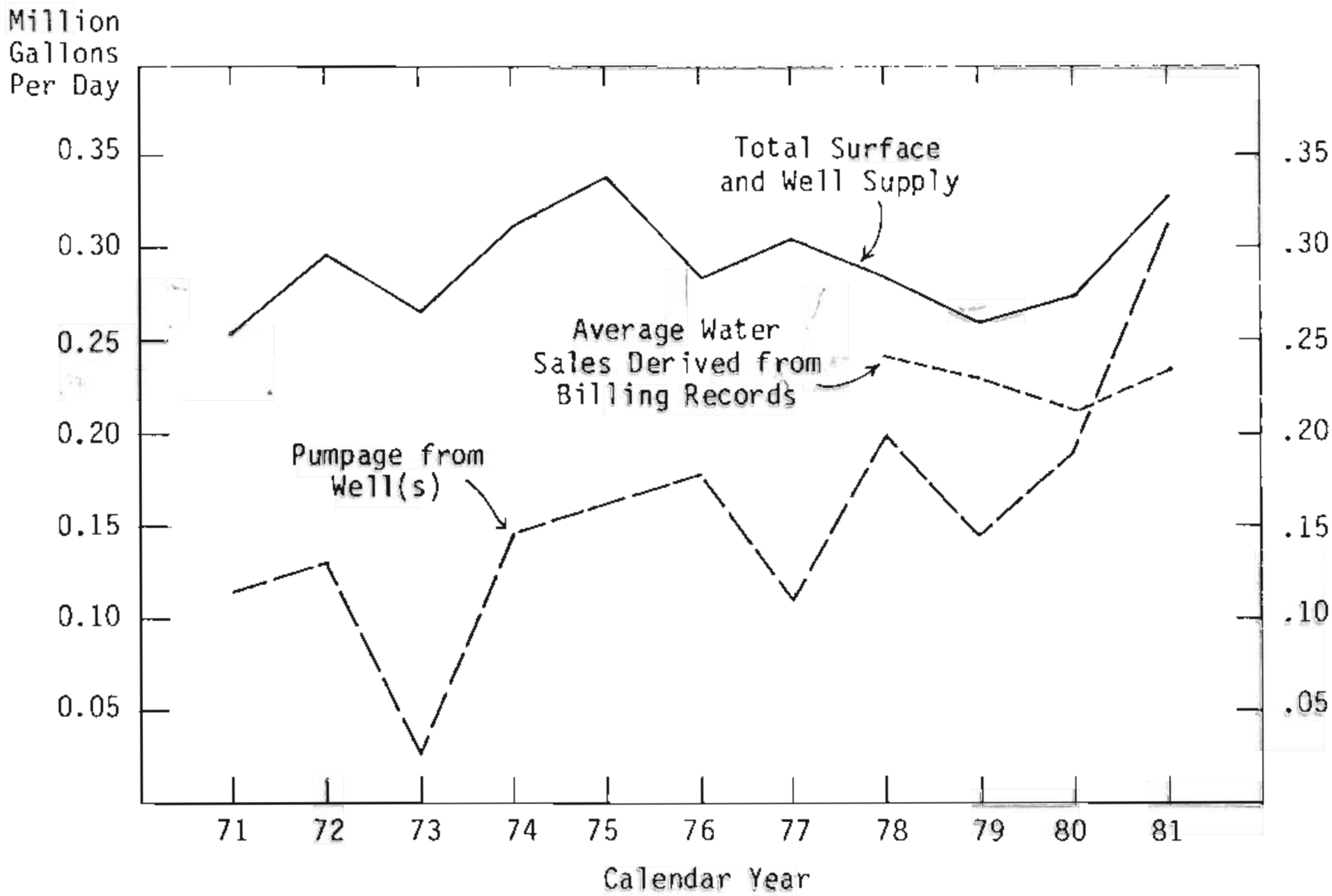
Numbers of DHHL Service Connections

	Numbers of Services		
	Homesteaders	Other	Total
Kalamaula	61	16	76
Kalae	30	6	36
Hoolehua			
- Farrington	72	7	79
- Lihipau	70	11	81
- Airport/Moomomi	36	28	64
Totals	269	68	336

Water supply and sales are depicted on Figure 19. The system's supply requirement was relatively stable through the 1970's, averaging 0.29 MGD over the last 10 years. DHHL does not compute the total volume of water sold. However, sales for the last four years were approximated for this study based on billings; they averaged 80 percent of total supply in this period. Supply to Kalamaula averaged 29 percent of the system-wide total in this same period; the balance was divided between Kalae and Hoolehua. From the standpoint of operational cost, the increased use of well water through the 1970's is notable.

Water Quality. Until recently, high turbidity (shown on Table 2) and evidence of bacterial contamination (shown by DOH quarterly analyses) due to the surface sources were frequent. Seven pressure filters, each rated at 50 GPM and all seven arrayed in parallel, were recently installed. A new gas chlorinator was also part of this CIP phase. Bacterial contamination in the last three DOH quarterly tests was not evident. Water clarity should be improved by the filters, although it is our understanding that they are currently experiencing some operational problems. Chemical quality of the water, illustrated by the annual DOH analyses on Table 9, is excellent.

Constraints. The cost of DHHL water in relation to its sales price is notable, particularly as reliance on wells increases. The sales price is $0.41 per thousand gallons, last increased in May 1978 from the previous $0.25 price. By contrast, the current energy cost of well pumping is calculated to be $0.94 per thousand gallons. If water is booster pumped to Kauluwai for distribution in Hoolehua, the additional energy cost is $0.41.



Source: Dept. of Hawaiian Home
Lands, Hoolehua, Molokai

Figure 19. DHHL System Water Use
in the 1970's

TABLE 9. Department of Health Chemical Analyses of the Department of Hawaiian Home Lands System (DOH System No. 230)

Constituent	Units	Maximum Allowable Contaminant Levels*	Date of Sample			
			12/11/78	7/23/79	7/22/80	9/28/81
Arsenic	mg/l	.05	.02	.02	.02	.02
Barium	mg/l	1	.8	.8	.8	.8
Cadmium	mg/l	.01	.005	.005	.005	.005
Chromium	mg/l	.05	.01	.01	.01	.01
Lead	mg/l	.05	.01	.02	.01	.02
Mercury	mg/l	.002	.0005	.0005	.0005	.0005
Nitrate (as N)	mg/l	10	.07	.36	.42	.39
Selenium	mg/l	.01	.01	.01	.01	.01
Silver	mg/l	.05	.03	.03	.03	.03
Flouride	mg/l	1.4	.2	.2	.2	.2
Chloride	mg/l	250**	22	57	95	72
Sodium	mg/l	none	N/A	25	32	31
Total Dissolved Solids	mg/l	500**	68	173	240	220

* Maximum contaminant levels are established by Federal National Interim Primary Drinking Water Standards and State Department of Health Regulations (Chapter 49).

** Secondary standards.

Source: Department of Health Drinking Water Program

Dedication of the water system to DWS has been considered previously. Substandard facilities, an impediment to DWS assumption in the past, is being remedied by the current CIP. Surplus supply and delivery capacity to Kalamaula when the 12-inch pipeline is completed and proximity to Kaunakakai make cross connection to the DWS system worthy of consideration. However, a 1978 amendment to the Hawaiian Homes Commission Act clouds the possibility of a transfer. Section 221-(2)-(f) of the Act now reads:

> *Water systems in the exclusive control of the department shall remain under its exclusive control. If any provision or the application of such provision is inconsistent with the provision contained herein, this section shall control.*

It believed that DHHL favors transferring operation, if not ownership, to DWS but may be prevented by Section 221-2-f. It has solicited (but not received) an interpretation by the State's Attorney General of the term "exclusive control." If DHHL retains ownership, operation of the water system by another entity may be possible.

Molokai Irrigation System (MIS)

The MIS was built from December 1957 to August 1962, financed by $5.5 million in State Funds and a $4.514 million loan from the (Federal) Bureau of Reclamation. The project was undertaken specifically for agriculture rather than domestic use; favorable terms of the loan derive from its agricultural designation. Chapter 175 of the Hawaii Revised Statutes assigns control of the system to the State DLNR. DLNR's Division of Water and Land Development ("DOWALD") is the operator of the system. It has a staff of three on Molokai for operation, routine maintenance, and administration. Water is sold for $0.08 per thousand gallons plus an acreage fee of $1.10 or $0.85/acre/month.

Sources and Transmission. Surface and groundwater sources supply the system via a 10-mile long tunnel and pipeline transmission link. Surface water is captured by low head diversion dams at four locations in Waikolu Valley. Three of these (two on Waikoku Stream tributaries and the other on Waikolu's main channel) gravity feed into the transmission tunnel's east portal at elevation 1000 feet. These have a combined diversion capacity of 15 MGD. The fourth diversion is at elevation 750 feet on Waikolu Stream, well below the east portal. Water captured there is pumped up to the tunnel. Groundwater sources include three drilled wells, one inside the tunnel and the others outside the east portal in Waikolu Valley, and water naturally intercepted by the transmission tunnel itself. Each well is outfitted with a 1.5 MGD pump. Flow intercepted by the tunnel is relatively stable at 1.8 MGD.

Transmission to storage at Kualapuu is comprised of a 5-mile long tunnel and then a 5-mile long pipeline. The tunnel is 8 ft. by 8 ft.; its bottom and 18 inches up each wall are paved with concrete. Capacity of the concrete channel is 21 MGD. The pipeline is 30-inch and 26-inch diameter and its capacity is matched to that of the tunnel.

Since the supply of surface water is variable and there is a substantial reservoir to store winter freshets and augment supply in dry periods, the capacity of the MIS must be defined by operational studies. Table 10 summarizes a study by DOWALD which puts the present yield at 7.6 MGD. This figure is a year-round average use rate; within-year usage variations are handled by reservoir accumulation and release, depending on the time of year.

Storage and Distribution. Storage is provided by a 104-acre, 1.4 billion gallon, butyl-lined, open reservoir in Kualapuu. It was completed in 1969, several years after the rest of the system was in operation. Wind and waves have damaged much of the above-water portion of the rubber liner. Gunite repair has been necessary and more is anticipated. The distribution pipeline network extends to Hawaiian Home lands in Hoolehua, the agricultural park south of the airport, and as far west as Mahana (see Figure 20). Virtually all distribution is by gravity from the reservoir, the pressure varying with the reservoir's water level which can range from 770 to 820 feet. A booster pump and 0.25 MG tank supply a limited number of users in higher elevations of Hoolehua.

Figure 21 illustrates MIS irrigated acreages and water use through the 1970's. Water sales averaged 1.4 MGD in the six years prior to Dole's termination of pineapple operations in Mauna Loa in 1975; the average has been 2.3 MGD in the six years since. Despite the loss of almost 4000 irrigated acres with Dole's closing, water use increased with the addition of Na Hua Ai's 150-acres of alfalfa, Akea Farm's 52 acres of diversified crops, Hawaiian Research's 125 acres of seed corn, and other diversified agriculture. Del Monte, with 3030 acres of pineapple, continues to be the system's largest user. It presently accounts for about 30 percent of total use, although this is down from its 50 percent share of use four to five years ago. Use by DWS' Kaunakakai system is not included in any of the above figures although its current water use rate is exceeded only by Del Monte and Na Hua Ai.

Water Quality. As Kalua Koi utilizes MIS water, the inorganic chemical analyses given previously in Table 9 show the water quality of the MIS. Since the MIS is designed for agricultural use, no treatment is provided. High turbidity in rainy periods does make filtration for drip irrigation necessary. Otherwise, the chemical quality of MIS water is excellent.

Constraints. Water sales are currently in the 2.7 to 3.0 MGD range, about 35 to 40 percent of the supply capability defined by DOWALD. A surplus conveyance capacity also exists in the extensive distribution network. The current surplus allows for agriculture development in the future, although it also means present revenues are relatively low. A comparison of revenue and expenses is presented below. The present imbalance is attributable to the closing of pineapple operations on Mauna Loa and slow growth of diversified agriculture in Hoolehua. Notably, the transmission rental by Kalua Koi provides one quarter of the system's revenue. Del Monte is the only ag-customer which contributes more.

TABLE 10. MIS Supply Capability Defined by Division of Water & Land Development Operational Studies

		MGD
Maximum Supply Rate		
Gravity Stream Diversion		15.0
Pumped Stream Diversion		4.0*
Wells (three)		3.9*
Tunnel Flow		1.8
	Total	24.7
Minimum Supply Rate (without Pumping)		
Gravity Stream Diversion		0.5
Tunnel Flow		1.8
	Total	2.3
System's Supply Capability**		
Supply from Sources		7.2
Reservoir Release		2.3
Losses to Evaporation and Spillage at the Reservoir		(1.0)
Distribution System Losses (10$\pm$%)		(0.9)
	Total	7.6

* Flow rate of the pumps is based on pumping 21 hours per day.

Source: State Department of Land & Natural Resources, Division of Water & Land Development

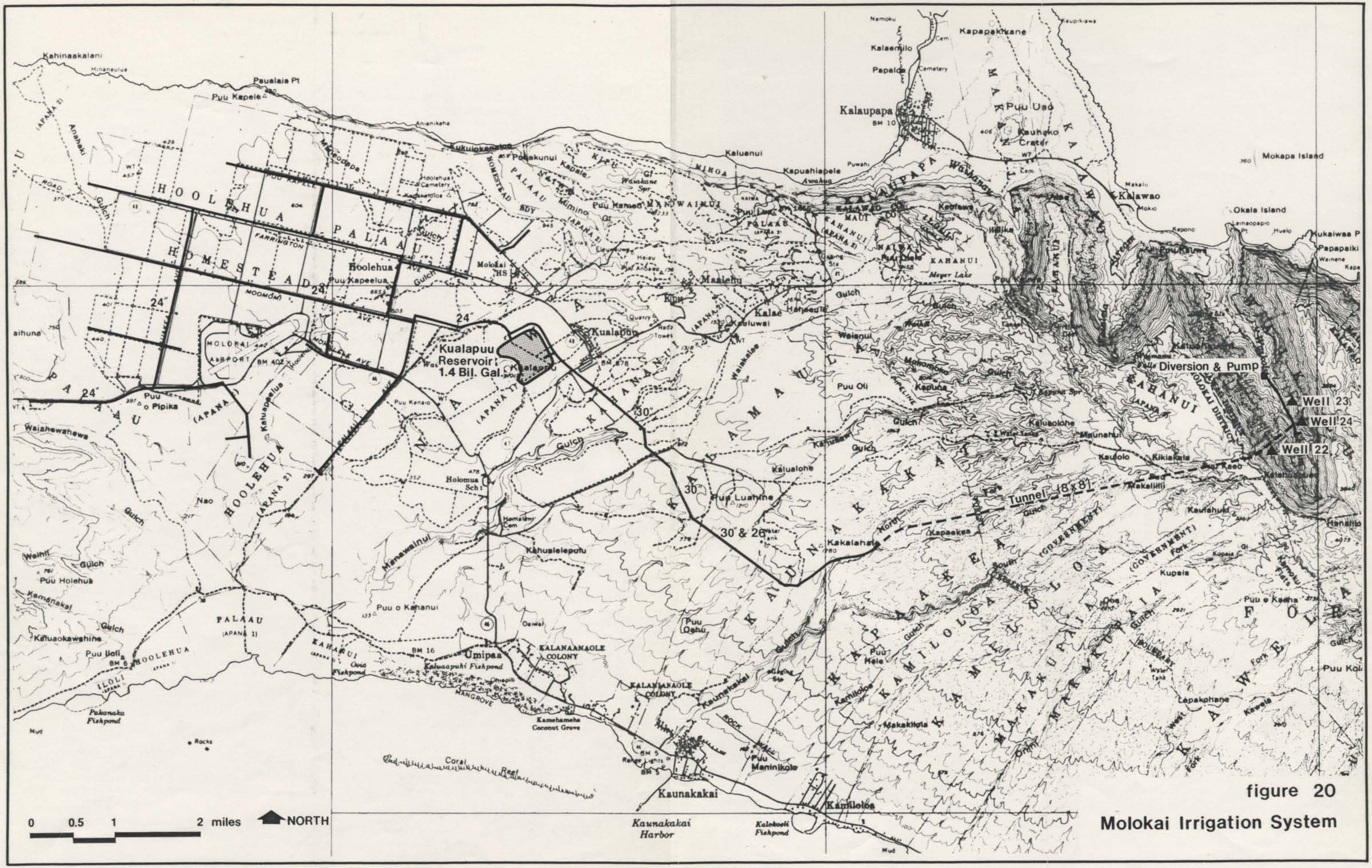
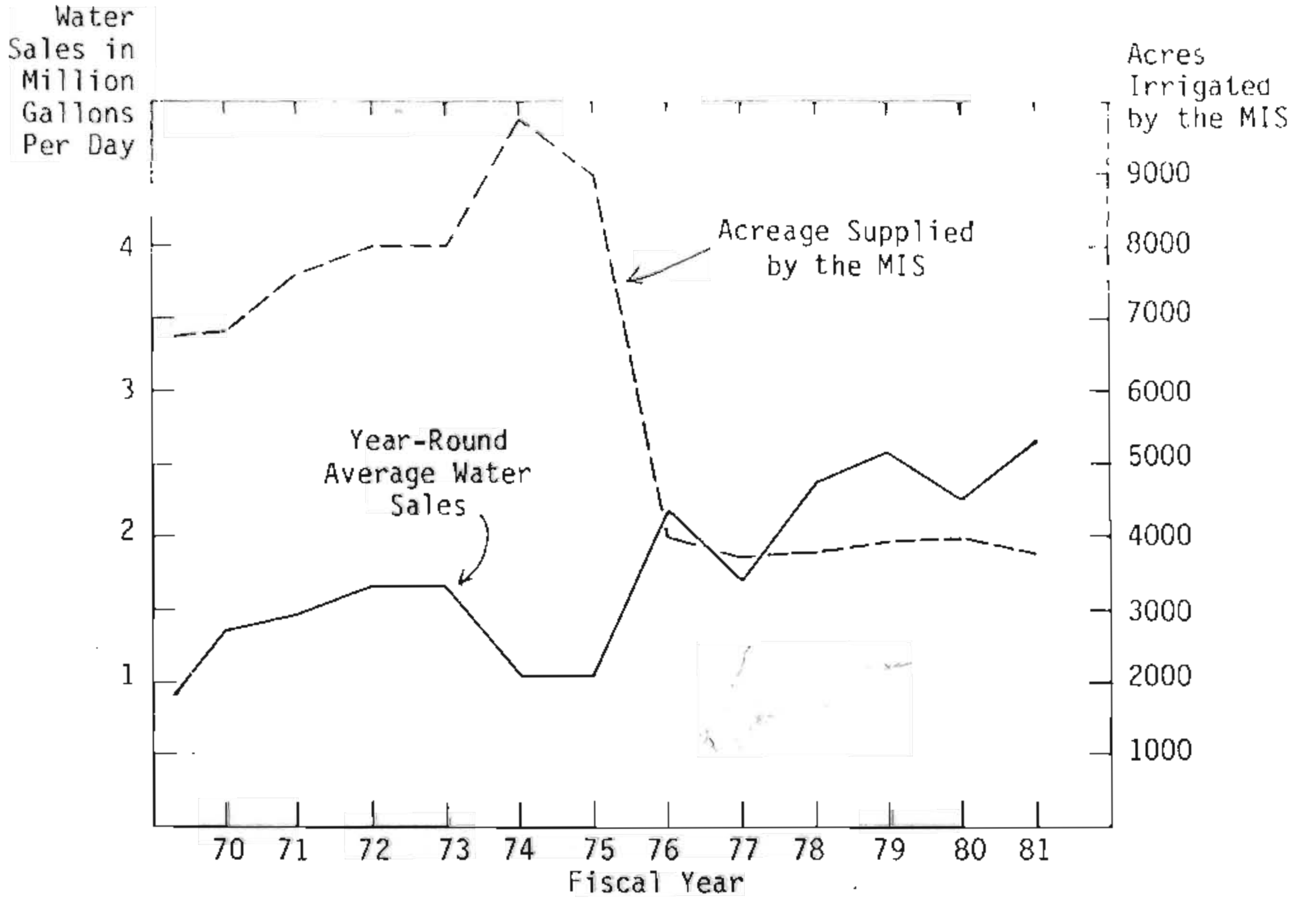
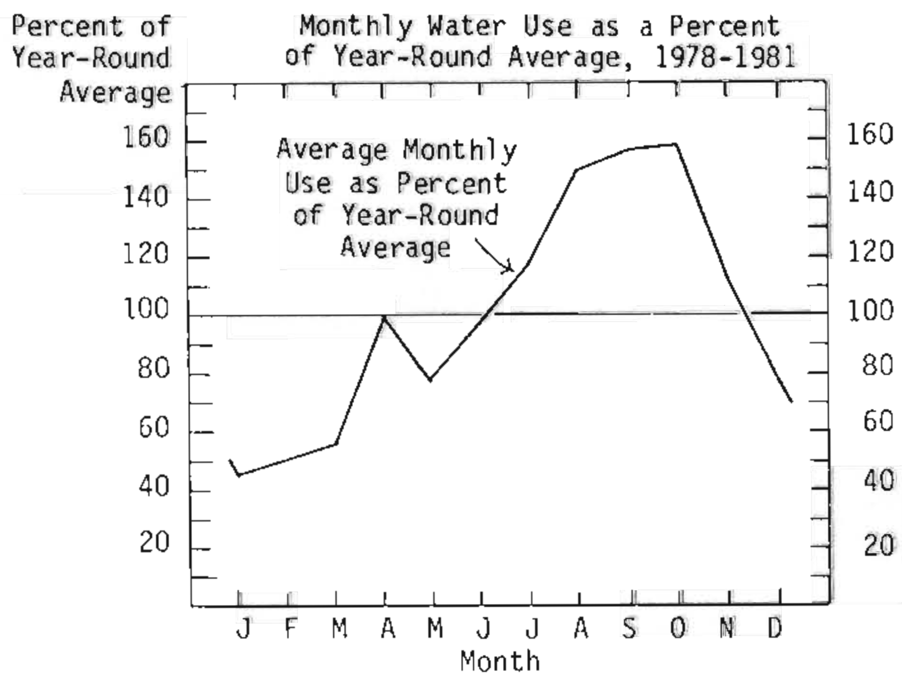


figure 20

Molokai Irrigation System





Sources: Annual Reports of Dept. of Land and Natural Resources

: Records of the Division of Water and Land Development

Figure 21. MIS Water Use in the 1970's

Estimated Current Revenues and Expenses of the
Molokai Irrigation System

Estimated Annual Revenues	
Water Sales @ $0.08 per 1000 gallons	$ 79,400 (1)
Acreage Fees @ $1.10/acre/month	48,800 (1)
Transmission Rental by Kalua Koi	45,000
Total Revenues	$173,200
Estimated Annual Expenses	
P & I on Bureau of Reclamation Loan	$177,500 (2)
Electrical Cost of Pumping	15,000 (3)
Personnel and Office Expenses	70,000 (4)
Equipment and Miscellaneous Expenses	15,000
Total Expenses	$277,500

(1) Based on water sales and acreages served in calendar year 1981.

(2) Principal and interest on payment by State DLNR in 1981.

(3) Pumping has been limited due to replacement of power lines and controls. DOWALD has budgeted $120,000 annually for pumping it expects to do in coming years.

(4) Three full-time employees and an office in Hoolehua.

Present surplus capacity is reserved for agricultural use. However, adding municipal use might be considered if institutional constraints could overcome. First, an amendment of the State-Bureau of Reclamation agreement would be required. The share of the loan which reflects the proportion of municipal use would be at an interest rate established by the Treasury Department. That rate is presently 9.352 percent and is expected to be 10 percent in the next fiscal year. Second, Chapter 175, Section 4 of the Hawaii Revised Statutes gives DHHL and its lessees a "prior right" of up to two-thirds of Waikolu Valley sources of the MIS. DHHL can exercise this right when it demonstrates an actual need. If municipal use is added, addition of supply at least equivalent to that use when the MIS capacity requires expansion should be a condition. Third, the MIS was built to foster agricultural development, and it can only be accomplished if water is available at an economic price. To this end, the addition of municipal use should be at a higher price than irrigation water and, in effect, aid in keeping the agricultural water price at an economically viable level.

PROJECTIONS OF FUTURE WATER USE

BASIS OF THE PROJECTIONS

Owing to variable population changes and land development expected for specific areas of Molokai, different water demand projection techniques are employed from one area to the next. In general, the projections are based on one or more of the following sources:

- census data;
- past and present water use rates as presented earlier in this report;
- "Molokai Community Plan" by EDAW, Inc., October 1981;
- "Molokai Regional Development Plan" by MKGK-Yamamoto, Inc., December 1979;
- "Kaunakakai Water System Study for the County of Maui" by Fukunaga & Associates, (draft) May 1981;
- "Engineering Report for Molokai Water System Improvement" by Park Engineering, Inc. for the Department of Hawaiian Home Lands, August 1977;
- development limitations establishd by State land use designations and County zoning;
- announced development plans and/or intentions of landowners;
- discussions with water system operators.

In this section of the report, water use projections are shown through 1990. In the next section of the report where economic evaluations of supply options are evaluated, projections of use through 2000 are given. These are simple extrapolations of the forecast growth from 1982 to 1990.

DIVISION OF THE ISLAND INTO REGIONS

On the basis of physical separation, existence of water supply links, and development potential, the island is considered in terms of three regions. The East Region covers the coastal area from Kamalo to Halawa Valley. It is presently served by two DWS systems, Ualapue and Halawa. The Central Molokai region includes Kaunakakai town, the Kawela Plantation development, the DHHL colony at Kalamaula, the Kalae and Kipu residential areas, Del Monte's Kualapuu community, the rural-agricultural area of Hoolehua, and major government facilities including schools and the airport. Six domestic systems and the State MIS serve this region. Despite its diversity and areal extent, proximity and interconnections of water supply links makes consideration as a single region appropriate. The West Molokai region consists of Mauna Loa and the Kalua Koi Resort. Growth in the Mauna Loa urban area will be tied to the success of the Kalua Koi Resort. Its residents are and will continue to be a majority of the Resort's employees.

WATER USE PROJECTION FOR THE EAST REGION

No water use projection is made for the Halawa Valley portion of the East Region. Water sales of the DWS system there did increase throughout the 1970's (refer to Figure 9), but the 2500 GPD current amount is still small in comparison to the use rate that occurred in the 1950's and 1960's and is well below the capacity of stream supply and transmission pipeline. There is no expectation of a substantial water use increase.

The service area of the DWS Ualapue system is comprised of Enumeration Districts 102 and 103 of the 1980 census less residents in the area from Honouliwai Stream to Halawa Valley. Including visitors at the 127-unit Wave Crest condominium, the de facto population is estimated to be 885 (see calculation below). Fukunaga & Associates (1981:Table 4) estimates the same population at 922 based on DWS service connections and an assumed average household size for each service connection.

Estimated 1980 Population in the Ualapue System Service Area

Resident Population in ED 102 and 103 (see Table 11)	784
Wave Crest (127 units, 2 people/unit, about 70 percent occupancy	175
Less Residents in 19 Households from Honouliwai Stream to Halawa Valley (estimated)	(-74)
De Facto Population in the Service Area . . .	885

As enumeration district boundaries differed in the 1970 and 1980 censuses, an accurate trend of population in this area is not available. However, water usage has been increasing; the number of DWS service connections rose steadily at 1.9 percent per year and water sales at 6.7 percent per year (refer back to Figure 6).

Using the trend of water use in the 1970's, desirable population growth and land use suggested in the "Molokai Community Plan," projections of water use and required supply capability through 1990 are presented in Figure 22. Average water sales are shown to be 0.21 MGD in 1990. Required supply, derived from water sales by adding 10 percent for unmetered use and losses and then multiplied by 1.5, would then be 0.35 MGD. This is less than present capacity of either of the two, 500 GPM turbine pumps at the Ualapue shaft even if pumpage is limited to 16 hours daily.

There are 4.36 miles along Kamehameha V Highway between the East and Central Regions which are not served by a public water system. This gap along the coast includes approximately nine residences (visible from the highway), a resident population of perhaps 30 to 50 people, and no other urban development. As far as is known, each residence has an individual water system. Other than these residences, most of the land is in large parcels. State land use classification is Agriculture (A) mauka of the highway and Conservation (C) on the makai side. Both the "Molokai Community Plan" and the "Molokai

TABLE 11. Resident Population Enumerated in the Census of 1970 and 1980

Area of Molokai	1970 Census Designation	1970 Census Resident Population	1980 Census Designation	1980 Census Resident Population	Average Annual Growth Rate, 1970 to 1980
East Molokai	CT 317	2,574	CT 317	3,574	+3.3%
- Kaunakakai	ED 49	1,070	ED 100	2,231	+7.6%
- East of Kamalo, Makai of Highway[1]	ED 50	274	ED 102	353	
- Balance of Census Tract	ED 51	1,230	ED 103	431	-1.1%
			ED 104	559	
West Molokai	CT 318	2,515	CT 318	2,331	-0.8%
- Kualapuu	ED 53	441	ED 105	502	+1.3%
- Mauna Loa	ED 54	872	ED 106	633	-3.3%
- North Hoolehua and Kalae-Kipu[2]	ED 55	886	ED 107	845	-0.5%
- Balance of Census Tract	ED 56	316	ED 108	351	+1.1%
Island Total Exclusive of Kalawao County		5,089		5,905	+1.5%

[1] The west end of this enumeration district changed from one census to the next. In 1970, the boundary was at Kamalo Harbor. In 1980, it was moved west of Kamahuehue pond.

[2] The boundary in Hoolehua between ED's 55 and 56 in 1970, identical to ED's 107 and 108 in 1980, was Hauakea and Farrington Avenues.

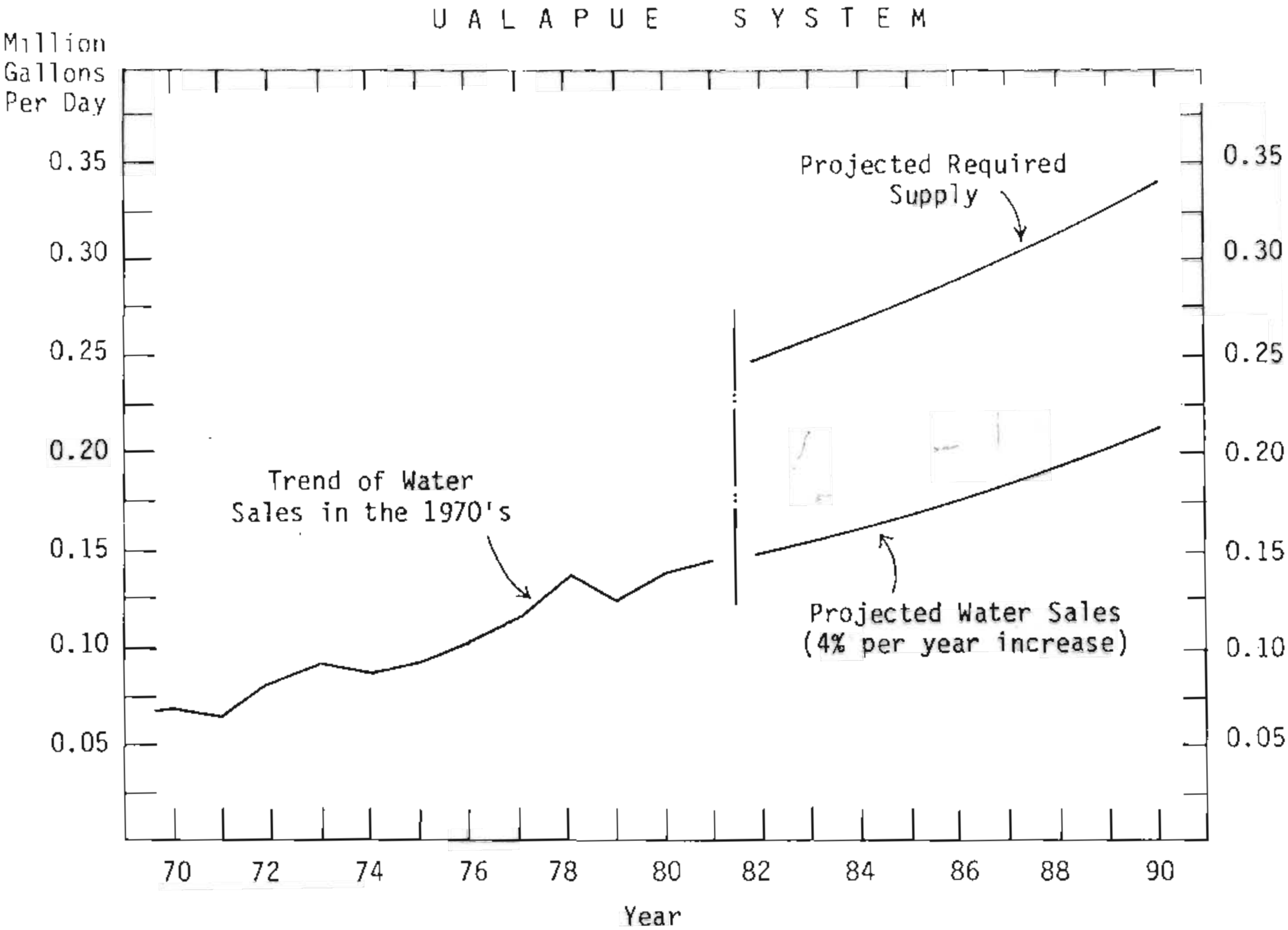


Figure 22. Projected Water Sales and Required Supply of the Ualapue System

Regional Development Plan" state that these classifications and the development intent of them should be maintained. For the purposes of this study, it has been assumed that new residences would construct individual, private water supplys; as such, extending distribution along the highway from the Ualapue or Kaunakakai systems is not an indicated need. If an agriculture subdivision similar to Kawela Plantation is developed, construction of a new water system or connection to the DWS Ualapue system at the developer's expense would be necessary.

WATER USE PROJECTION FOR THE CENTRAL REGION

It is estimated that the 1980 de facto population in the Central Region was 5000*, approximately 80 percent of the island's total. The area is served by six domestic water supply systems and the State's MIS. Combined domestic water consumption is 1.0 MGD at present and is projected to be 2.1 MGD in 1990, equivalent to an 8 percent per year increase (see Table 12). The basis of each system's projection is explained below.

Kawela Plantation

Although the Kawela Plantation water system has been completed, construction of the remainder of the project is ongoing. Water use is now limited to construction and the project's nursery. Eventually, the system will supply 210 lots, presumably with one residence on each lot. Allowing 600 GPD per residence, average water use would be 130,000 GPD. With 10 percent for miscellaneous losses and a 1.5 maximum day/peak season factor, the supply capacity should be 210,000 GPD. This can be met operating two of the system's three 75 GPM well pumps 23 hours a day or all three pumps for 15 hours. A separate system will supply irrigation water by scheduled withdrawal and at low pressure. The limited potential of the irrigation system has not been considered here.

DWS - Kaunakakai

Population in the Kaunakakai enumeration district rose at an average of 7.6 percent per year in the 1970's (refer to Table 11). Water sales of the DWS system, which serves the enumeration district and the coastal area beyond Kamiloloa, grew at 7.9 percent per year in the same period. These trends and land use proposed in the "Molokai Community Plan" are the basis for the water use forecast shown on Figure 23. Water sales are shown to increase at 5 percent per year, amounting to 1.0 MGD average sales in 1990 and requiring a supply capability of at least 1.6 MGD. The Conant-Kawela well is the sole supply controlled by DWS and it is presently pumped at 0.3 to 0.35 MGD. High salinity during the 1948 pump test at 800 GPM, salinity increases experienced by DWS during high pumpage in dry periods, and proximity to Kawela Plantation wells all caution against extracting substantially more than the present pumpage rate on a long term basis.

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* The estimate is comprised of 2,790 residents in ED 100 and 104 in CT 317, 1980 residents in ED 105, 107, and 108 in CT 318, and an average of 220 visitors in the 160 units of Pau Hana Inn, Hotel Molokai, and Molokai Shores.

TABLE 12. Present and Projected Domestic Water Use in Molokai's Central Region

Water System	Present Service Area	Present Average Water Sales or Use (MGD)	Projection for 1990: Basis for the Projection	Projection for 1990: Average Water Use (MGD)	Projection for 1990: Required Supply Capacity (MGD)
Kawela Plantation	210 agricultural lots in the vicinity of Kawela Gulch	Temporary construction and nursery use only	one residence on each of the project's 210 lots	0.13	0.21
DWS - Kaunakakai	820 service connections from Kaunakakai town to Kawela	0.64	5% per year increase based on 1970's trend and the "Molokai Regional Development Plan"	0.99	1.64
DWS - Kalae	59 residential service connections in Kalae	0.019	4% per year increase based on 1970's trend and the "Molokai Regional Development Plan"	0.027	0.044
Del Monte - Kualapuu	502 residents and the plantation office and maintenance yard in Kualapuu	0.08 (est.)	plantation to continue but with no growth	0.08	0.132
Molokai Ranch - Kipu	21 residences in the Kipu area	0.015 (est.)	present use plus 40 lots of an 80-lot subdivision	0.055	0.091
Industrial Development - Lower Manawainui	5 residences, Pacific Concrete & Rock Co., Molokai Electric's new power plant and Friendly Isle Construction now served by the Molokai Ranch System	0.01 (est.)	50 acres of industrial development at 4000 GPD/acre	0.20	0.33
DHHL - Kalamaula	76 service connections, including 61 homesteader households, five churches, and several commercial services	0.075	present demand plus an additional 115 residential and agri-cultural lots and 20 acres of commercial-industrial development	0.23	0.38
DHHL - Kalae	36 service connections, including 30 homesteaders, the FAA (13 houses, 6 currently occupied), and other non-homesteader services but excluding supply to DWS-Kalae	0.020	3% per year increase over present use but excluding DWS-Kalae	0.026	0.043
DHHL - Hoolehua	224 service connections, including 178 homesteaders, junior and senior high school, and the airport	0.145	present use plus a planned 100-lot subdivision and some increased usage by schools and other government facilities	0.22	0.363
Total for Central Molokai Region		1.00		1.96	3.23

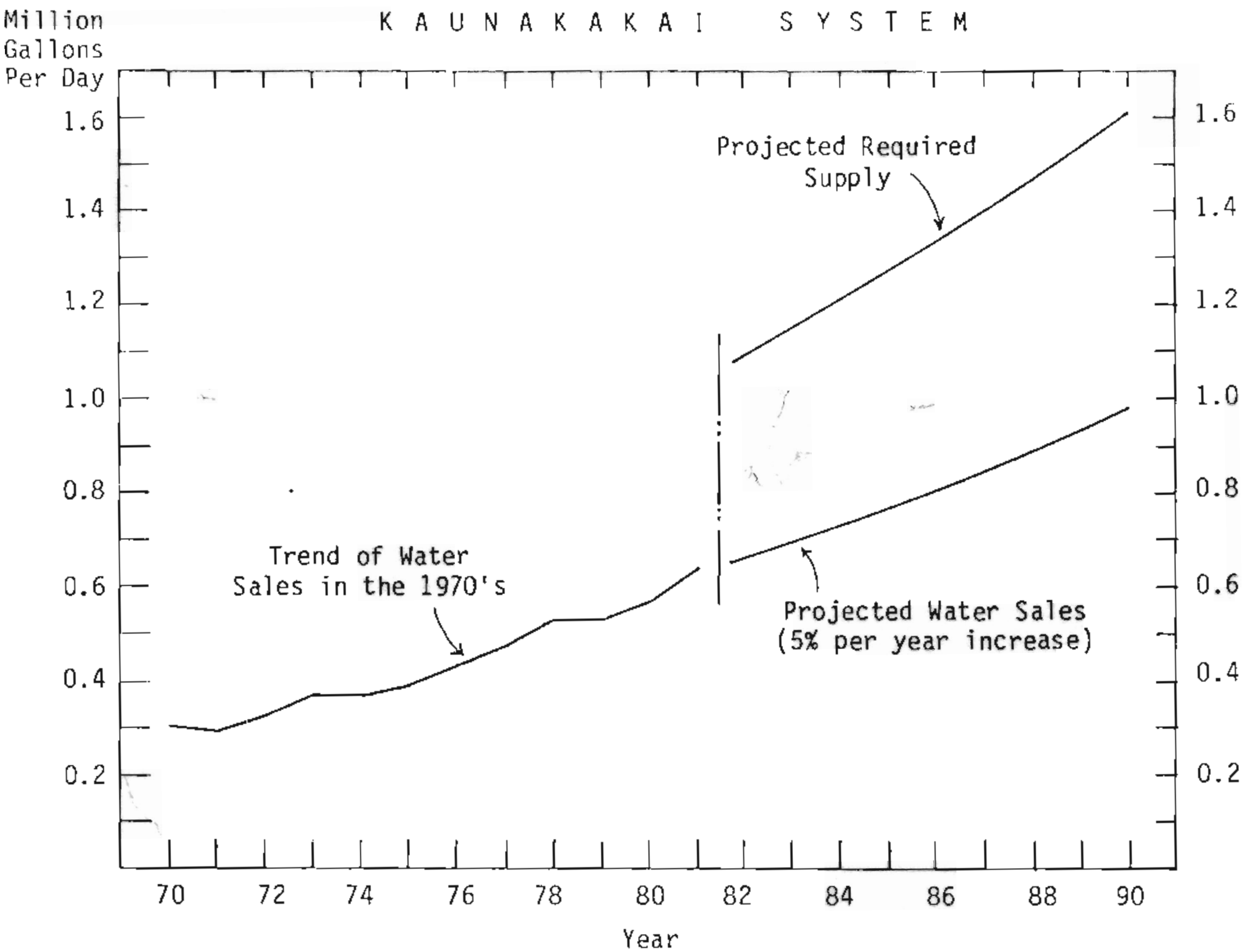


Figure 23. Projected Water Sales and Required Supply of the Kaunakakai System

Continued use of the Kaunakakai system's other supply source, the MIS, is problematical. Its use has evolved without a formal agreement specifying amounts and costs and is contrary to the loan agreement between DLNR and the Bureau of Reclamation. Its status, as well as future supply requirements forecast for the system, demonstrate an immediate need to expand supply capability.

DWS - Kalae

Water sales of the Kalae system increased at 4 percent per year in the 1970's. Citing the area's desireability for residential use, the "Molokai Regional Development Plan" suggests a population growth rate of 2.9 percent per year, the highest on Molokai except for resort-related growth on the island's west end. Based on this, an increase in water sales of 4 percent per year is shown on Figure 24. Sales of 27,000 GPD in 1990, which would require a supply capacity of 44,000 GPD, are forecast.

Present supply capacity of the R.W. Meyer Estate tunnels is estimated to be 31,500 GPD. This is based on DWS records of tunnel flow in dry periods which amount to about 25,000 GPD from Waikalae and 6,500 GPD from Waialala. (DWS is the sole user of the tunnel water.) The other source for the Kalae system is water purchased from DHHL at its Kauluwai tank and pumped to Kalae. CIP expansion of the DHHL system has allocated up to 35,000 GPD for DWS-Kalae (Park Engineering, 1977:22).

Del Monte - Kualapuu

Domestic use of 80,000 GPD by the Del Monte system is estimated based on the population of 502 in 1980 (enumeration district 105 in census tract 318) and uses at the plantation office and maintenance yard. Although the population of Kualapuu did increase between 1970 and 1980, Del Monte does not anticipate future growth. For this reason, the present water use rate is also the forecast rate for 1990.

Molokai Ranch - Kipu

Molokai Ranch plans to develop 80 residential lots in Puu Kolea, supplying water to them by gravity from the same tanks which now supply its 21 residences in Kipu. It has made a connection and installed a pump at the DHHL tank in Kauluwai. It is intended that DHHL water will supply the existing 21 and 80 new residences. The pipeline from the Ranch's mountain sources to Kipu will be maintained as a standby supply.

Industrial Development - Lower Manawainui

"Molokai Community Plan" designates a total of 200 acres for heavy industrial use in lower Manawainui. Molokai Electric and an existing seed corn operation occupy 110 acres of this land and the balance was expected to develop by the year 2000. Molokai Ranch recently submitted a petition to reclassify 90 acres of this area from Agriculture to Urban designation to permit industrial development. A dual water system was proposed in the Ranch's application: 1,000 GPD per acre for potable use to supplied by the Molokai Ranch system; a brackish well water system for fire protection and possible irrigation use. The Land Use Commission did reclassify 67 of the 90

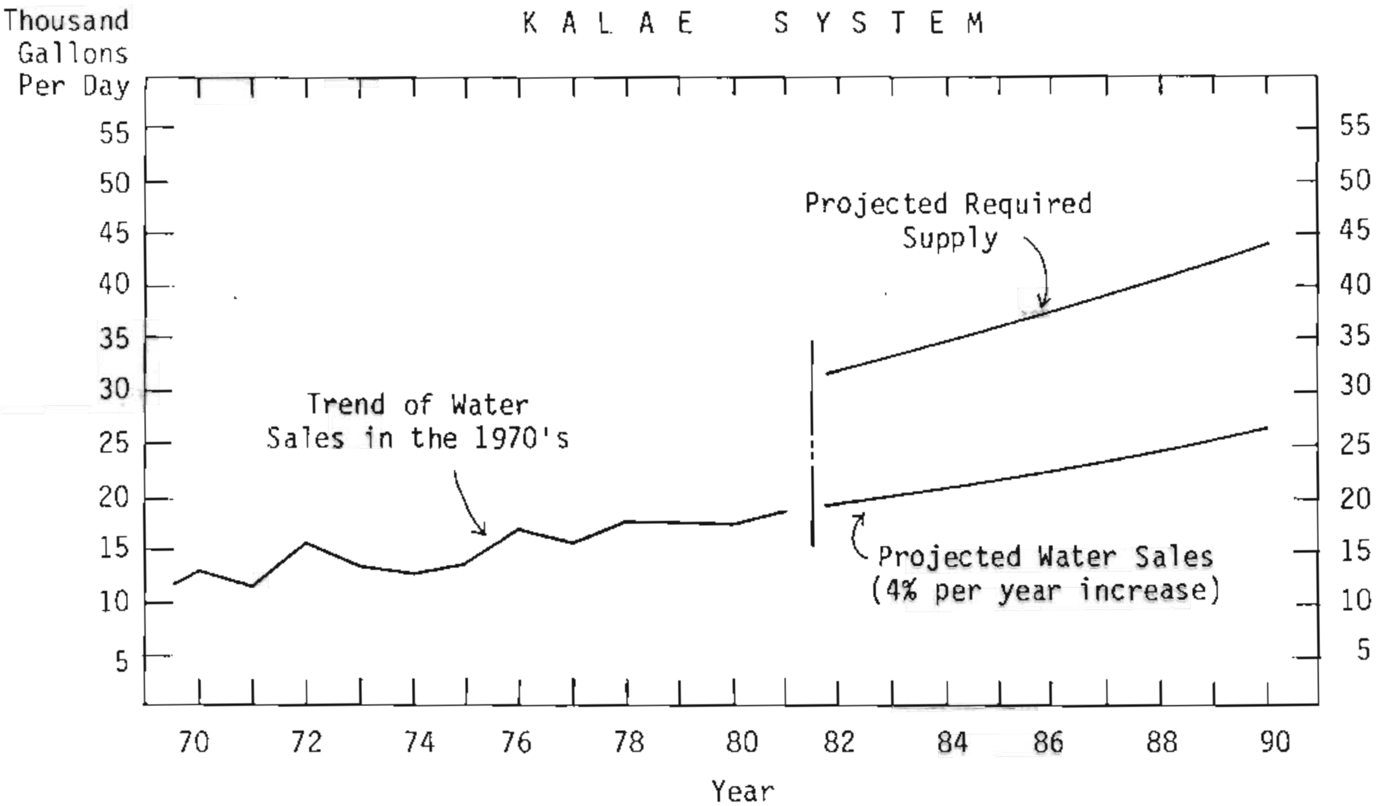


Figure 24. Projected Water Sales and Required Supply of the Kalae System

petitioned acres, 11 acres of which are in drainage gulch and a proposed silting basin.

Based on the "Molokai Community Plan" allocation, a net of 56 acres for industrial development by Molokai Ranch would provide sufficient area through 1990. If it is supplied by the Molokai Ranch system, industrial activities may be limited by the availability of water. To remove water supply as a constraint, a supply of up to 4,000 GPD per acre should be available. This rate is the basis for projected water use in Table 12.

DHHL - Kalamaula

Using billing records, current water use by the 76 service connections in Kalamaula is about 75,000 GPD; this is equivalent to an average of 985 GPD per service connection. DHHL is currently working on a 20-year master plan for Kalamaula. Options being considered range from a relatively high density of 460 residential units on 355 acres to an agricultural orientation with 143 lots on 300 acres. Common to each option are a total 100 acres in three economic development zones and a cultural-recreational park. To project water use, it is assumed that: (i) a development option featuring 230 ag-residential lots on 250 acres is chosen by DHHL; (ii) half of the lots are developed and occupied by 1990; (iii) water use per lot is the same as the present average use per service connection (this accounts a second house and/or modest irrigation use in addition to potable use at the principal residence); (iv) commercial/industrial development in the economic zones amount to 20 acres to 2,000 GPD per acre by 1990); and (v) cultural-recreational water use is nominal.

DHHL - Kalae

DHHL has planned to supply up to 35,000 GPD to DWS-Kalae and to provide water for an 80-lot subdivision proposed by Molokai Ranch. Allocations of water for these appear elsewhere in Table 12, however, and are thus not included in the projection for DHHL-Kalae. DHHL has no development plans of its own in this area. Accordingly, present use is shown to increase at 3 percent per year in Table 12, reflecting a modest increase in use per service connection and/or the addition of several new services.

DHHL - Hoolehua

DHHL has plans for a 100-lot subdivision in Hoolehua (Park Engineering, 1977:22). In addition to this, some increase in water use at the elementary, intermediate, and high schools and at the airport should be anticipated. The projection of water use on Table 12 includes 500 GPD for the 100 new lots, 10,000 GPD more water use in the complex of schools, and 10,000 GPD more in the airport area. These are added to the current usage of 130,000 GPD to reach a total of 200,000 GPD in 1990.

Molokai Irrigation System (MIS)

Water use forecasts on Table 12 are limited to potable systems. The MIS, an irrigation system, is not included in the table. However, its present and possible future use to supplement potable systems dictates its discussion here. As noted previously, MIS irrigation use increased through the 1970's despite the loss of almost 4000 acres of pineapple lands in Mauna Loa. Future irrigation water demand could include: the Hikiola project, some 527 acres of alfalfa to be developed in four increments; expansion of Na Hua Ai to triple its present 150 alfalfa acres; greater pineapple irrigation through drip conversion by Del Monte and up to 3,000 new acres by United Brands; expansion of diversified agriculture, particularly in the Molokai Task Force agricultural park; and a biomass energy farm to produce koa haole and/or hay for the island's power plant.

Potential irrigation demand amounts to more than 12 MGD which would, according to preliminary plans, be realized some time in the 1980's. A projection of what is felt will be the actual demand, based on no growth for pineapple, moderate growth by other, current users, and some expansion of alfalfa, is given on Figure 25. An annual increase of 7.3 percent is shown, although actual growth will probably occur as discrete jumps. This growth rate is less than the potential but is greater than what has occurred to date.

Using the projected growth on Figure 25, the MIS' current 7.6 MGD capacity would be exceeded in about 1995. If domestic use is added to the system, the capacity would be exceeded sooner.

WATER USE PROJECTION FOR THE WEST REGION

Potable water use in the West Region is projected from plans for the Kalua Koi Resort and population growth in Mauna Loa that the Resort's success is likely to generate. Irrigation and other, non-potable supply that Molokai Ranch may require is not specifically estimated.

Kalua Koi Resort

Year-round average water use of the fully developed Kalua Koi Resort within its urban- and ag-designated areas is compiled on Table 13. The total of 1.85 MGD is based on full hotel and condominium occupancy. Adding 10 percent for unmetered use and losses and then multiplying by 1.5 for maximum day/peak season use above the year-round average, Kalua Koi should have a supply capable of up to 3.05 MGD on a seasonal basis. At present, its supply is limited to 2.0 MGD, the maximum transmission rate allowed through MIS pipelines.

Mauna Loa

The population of Mauna Loa has declined significantly since the pineapple plantation closed. Census counts of 1970 and 1980 set the rate of decline at 3.3 percent per year (refer to Table 11). Enrollment at Mauna Loa elementary school declined at a more rapid 5.6 percent, suggesting a change in age distribution is also occurring. Growth of Kalua Koi Resort will reverse this trend, however. Kalua Koi and the Sheraton Hotel estimate that half of their employees reside in Mauna Loa. Proximity, recent acquisition of 100 acres of land for a possible housing project by the County, and other factors indicate that the trend of Resort employees living in Mauna Loa will continue as the Resort grows. Using Kalua Koi's estimate that the Resort will ultimately provide 1400 jobs, a population increase of 1100 people directly from these jobs can be derived:

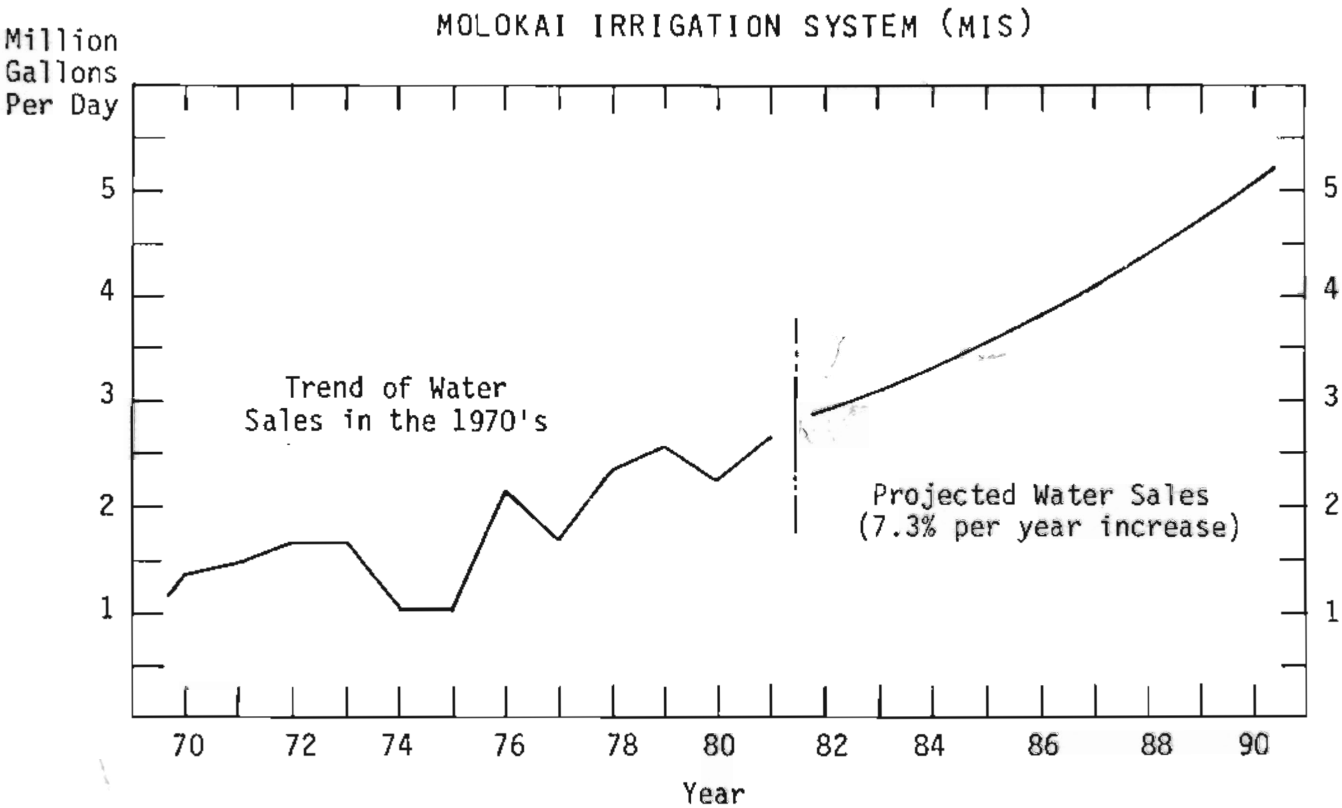


Figure 25. Trend of Water Sales of the MIS Extrapolated to 1990

TABLE 13. Potential Water Demand of the Kalua Koi Resort Based on Existing, Planned, and Developable Parcels

Development Parcel	Acres	Number of Residential Units	Per Unit Average Water Use (GPD)	Potential Average Water Demand (MGD)
Existing Development				
Sheraton hotel	29	292	550	0.161
Paniolo Hale condo	9	78	400	0.031
Ke Nani Kai condo	15	120	400	0.048
Moana Makani ag. subd.	1603	34	1000	0.034
Molokai Fairways SF resid.	8	16	550	0.009
Golf Course Clubhouse	--	--	--	0.020
Golf Course Irrigation	212	--	See Note 1	0.140
Planned Projects				
Pacific Bay hotel	42	300	550	0.165
Pacific Bay condo	18	170	400	0.068
Puu Maika condo	9	90	400	0.036
Kawakiu Villas	34	350	400	0.140
Papohaku Ranchlands	3400	272	1000	0.272
Other Developable Parcels				
Kaiaka hotel site	22	375	550	0.206
Agricultural lots	176	40	1000	0.040
Two A-1 parcels	33	275	400	0.110
R-2 residential	25	25	550	0.014
Two HM parcels	11	110	400	0.044
A-2 parcel	24	240	400	0.096
Three Resort Business parcels	20	--	4000	0.080
Four Recreation/Park Sites	28	--	3000	0.084
Unplanned	25	--	4000	0.050
Total Potential Water Demand (MGD)				1.85

Notes:

1. Irrigation of the existing golf course and other common areas averages about 0.47 MGD and is as high as 0.75 MGD in dry periods. As the resort develops, treated sewage effluent will become a significant portion of the irrigation supply. Effluent from nearby hotels (Sheraton and Kaiaka) and condominiums (Paniolo Hale, Pacific Bay, Puu Maika, Ke Nani Kai, and two HM parcels) will have a combined average water use of 0.69 MGD. Based on this, available sewage effluent for irrigation would average 0.34 MGD.

2. Average water use by the 292-room Sheraton Hotel has ranged from 440 to 512 GPD per room. Average use in the table above is 550 GPD per room to account for an increase in occupancy rate as the resort develops.

3. Neither of the two existing condominiums (Paniolo Hale and Ke Nani Kai) has been operating long enough to have established a water use pattern. The 400 GPD per unit used here is an estimate.

4. Potential water use within the agricultural lots of 1000 GPD per lot assumes about 50 percent for domestic purposes and the balance for agriculture or livestock.

(1) Allowing for people who will hold two jobs, the 1400 jobs will be taken by 1310 different individuals (this is based on the visitor industry's 0.94 individual per job ratio).

(2) Half of these individuals, i.e. 655 people, will reside in Mauna Loa (this is based on the make-up of present employees).

(3) Of the 655 individuals, 125 will be present residents who are already working (approximately 100) or are currently unemployed (25 using State Department of Labor estimates); the balance of 530 job-holders will be new Mauna Loa residents.

(4) Using 1.45 job-holders per household and an average household size of 3.0 individuals, 530 Mauna Loa-residing employees will increase the Mauna Loa population by 1100 (530 ÷ 1.45 x 3.0).

In addition to the 1100 population increase by direct employment, multiplier effects will generate commercial and service-related employment in Mauna Loa. Generally, an island-wide multiplier of 0.2 jobs per direct tourist employment job is used. Assuming that one half of these locate in Mauna Loa, population increase by indirect employment may be 10 percent of the direct employment population or 110 people. Including the present 630 residents, the 1990 population may be 1840 people. On Table 14, an average water use of about 210,000 GPD for this population is projected. Allowing for losses and seasonal variation in use, the source of supply should be able to provide up to 350,000 GPD.

TABLE 14. Existing and Projected Potable Water Use in Mauna Loa (Irrigation and Other Non-Potable Water Use by Molokai Ranch is not Included)

Components of Water Use	Unit Water Use Rate (GPD)	Existing Water Use		Projected Water Use	
		No. of Units	Average Water Use (GPD)	No. of Units	Average Use (GPD)
Resident Population	100/person	633	63,300	1,840	184,000
Commercial Establishments	500 ea.	6	3,000	12	6,000
Mauna Loa Elementary School	30 pupil	88	2,700	300	9,000
Other Government Services	--	--	2,000	--	4,000
Recreational Facilities	--		4,000	--	8,000
TOTALS			75,000		211,000

FUTURE WATER SUPPLY OPTIONS

INDICATED SYSTEM IMPROVEMENTS AND EXPANSIONS

To illustrate where improvements or expansions will be needed, Table 15 compares supply capacities to projected requirements in 1990. There are four areas where expansions of supply capacity will be needed:

(1) The DWS-Kaunakakai System requires an immediate source to end its dependence on the State MIS. Without the MIS, the present supply deficit is approximately 0.7 MGD; by 1990, the deficit is projected to be 1.3 MGD.

(2) Initial industrial development in lower Manawainui is likely to be on Molokai Ranch land and may be supplied by the Ranch system. That system has limited available supply. To avoid restrictions of the type of industrial development, supply by the DHHL system is more appropriate.

(3) Planned development of the Kalua Koi Resort requires a supply of at least 3 MGD. The Resort is presently restricted by its agreement with the State to transmission through the MIS of 2 MGD.

(4) Residences and related services will be developed in Mauna Loa in response to growth of the Kalua Koi Resort. The Molokai Ranch system does not have sufficient capacity and cannot meet State drinking water standards to supply this development.

In addition to these shortfalls in supply, two other aspects of system operation relevant to water supply planning are discussed. First, there are a number of water pumping lifts where the cost of electrical energy alone approaches $1.00 per thousand gallons, more than the eventual sales price of the water pumped. In the future, reliance on well pumping lifts will be even greater. Savings in the cost of pumping can be achieved through energy recovery by in-line hydro-generators or by conversion to diesel. Second, in Kalae-Kipu, facilities of DWS, Molokai Ranch, DHHL, and the FAA are redundant. Consolidation to achieve more efficient operation and resource utilization deserves investigation.

BASIS FOR EVALUATING WATER SUPPLY OPTIONS

Various supply options are presented first as an array of capital and operating costs. The operating costs given are restricted to those associated with well, booster pump, and/or treatment operation. After the costs of all alternatives are presented, comparisons among them are made assuming capital expenditures are financed by 13 percent, 20-year bonds.

To develop the array of capital expenditures associated with each alternative, terms to define rates of water use and supply capacities are used. These are defined as follows:

(1) metered use or metered sales: the year-round average water use by customers;

(2) total water produced: metered use plus 10 percent for miscellaneous unmetered use and losses;

TABLE 15. Comparison of Projected Supply Requirements and Capacities

Region and System	Present Water Use and Supply Capacity			Projected 1990* Water Use and Supply Capacity		
	Present Average Water Use (MGD)	Required Supply Capacity (MGD)	Existing Supply Capacity (MGD)	Projected Average Water Use (MGD)	Required Supply Capacity (MGD)	Surplus or Deficit (-) Supply (MGD)
East Region						
DWS - Ualapue	0.145	0.239	0.480	0.21	0.34	0.14
Central Region						
Kawela Plantation	--	--	0.210	0.13	0.21	0.00
DWS - Kaunakakai	0.640	1.056	0.336	0.99	1.64	(-)1.3
DWS - Kalae	0.019	0.031	0.031	0.027	0.044	(-)0.013
Molokai Ranch - Kipu	0.015	0.025	As Required	0.055	0.091	(-)0.091
Industrial Area - Lower Manawainui	0.010	0.016	--	0.20	0.33	(-)0.33
Del Monte - Kualapuu	0.080	0.132	--	0.08	0.13	0.00
DHHL - Kalamaula	0.075	0.124		0.23	0.38	
DHHL - Kalae	0.020	0.033	0.75	0.026	0.043	(-)0.03
DHHL - Hoolehua	0.145	0.239		0.22	0.36	
Molokai Irrigation System (MIS)	2.6±	2.6±	7.6	5±	5±	2.6
West Molokai Region						
Kalua Koi Resort	0.850	1.400	2.0	1.85	3.05	(-)1.05
Mauna Loa	0.075	0.124	--	0.21	0.35	(-)0.2±

*Figures given for the Kalua Koi Resort are based on current development plans. These may not be fully realized by 1990.

(3) required supply capacity: 1.5 times total water consumption or, equivalently, 1.65 times metered use; and

(4) defined supply capacity: maximum supply capability of a water system defined by the limit of pumps or transmission pipelines.

Sizes of transmission pipelines are based on providing the required supply rates with water velocities of 7 feet per second ("fps") or less. Well and booster pumps are sized to provide the required supply operating 16 hours or less each day. Standby capacity equivalent to the largest pump is also a requirement for booster and well pump facilities. All of the above are DWS design criteria.

WATER SUPPLY OPTIONS FOR THE DWS-KAUNAKAKAI SYSTEM

Options Evaluated

Four supply options are evaluated for the Kaunakakai system: (1) continuing use of the MIS; (2) connecting to the DHHL system at its transmission pipeline to Kalamaula; (3) developing new wells inland of Kaunakakai; and (4) connecting to the DWS-Ualapue system. The first two of these rely on State systems. It is assumed that a contribution by DWS at least equivalent to the supply it utilizes would be made at the time when expansion of either of the State systems occurs.

Option 1: Use of the MIS

Use of the MIS would require consent of the State and renegotiation of the State's loan from the Bureau of Reclamation. With these accomplished, three major capital investments by DWS would be required through year 2000. In chronological sequence, these would be:

1. Installation of Treatment Facilities and Parallel Transmission Pipeline. Installation of treatment facilities would be required immediately for MIS water to meet State DOH quality standards. Injection of a flocculating agent at DWS' screen box on the pipeline to the MIS, mixing of it in the pipeline itself, and two 980 GPM automatic gravity filters at the 1.0 MG Kaunakakai tank are recommended. One filter would provide standby capacity.

The existing 6-inch transmission pipeline to the MIS system can convey 0.89 MGD (applying the maximum velocity criterion). Adding the 0.34 MGD capacity of the Conant-Kawela well (defined by its 350 GPM pump operating 16 hours) provides a 1.23 MGD defined supply capacity. The projected supply requirement exceeds this in 1984 (see Figure 26). Installation of a parallel, 8-inch, 8,300 feet long pipeline would bring transmission capacity to 2.47 MGD, adequate through year 2000. The new pipeline should be undertaken concurrent with installation of treatment facilities. Estimated cost is $1,070,000.

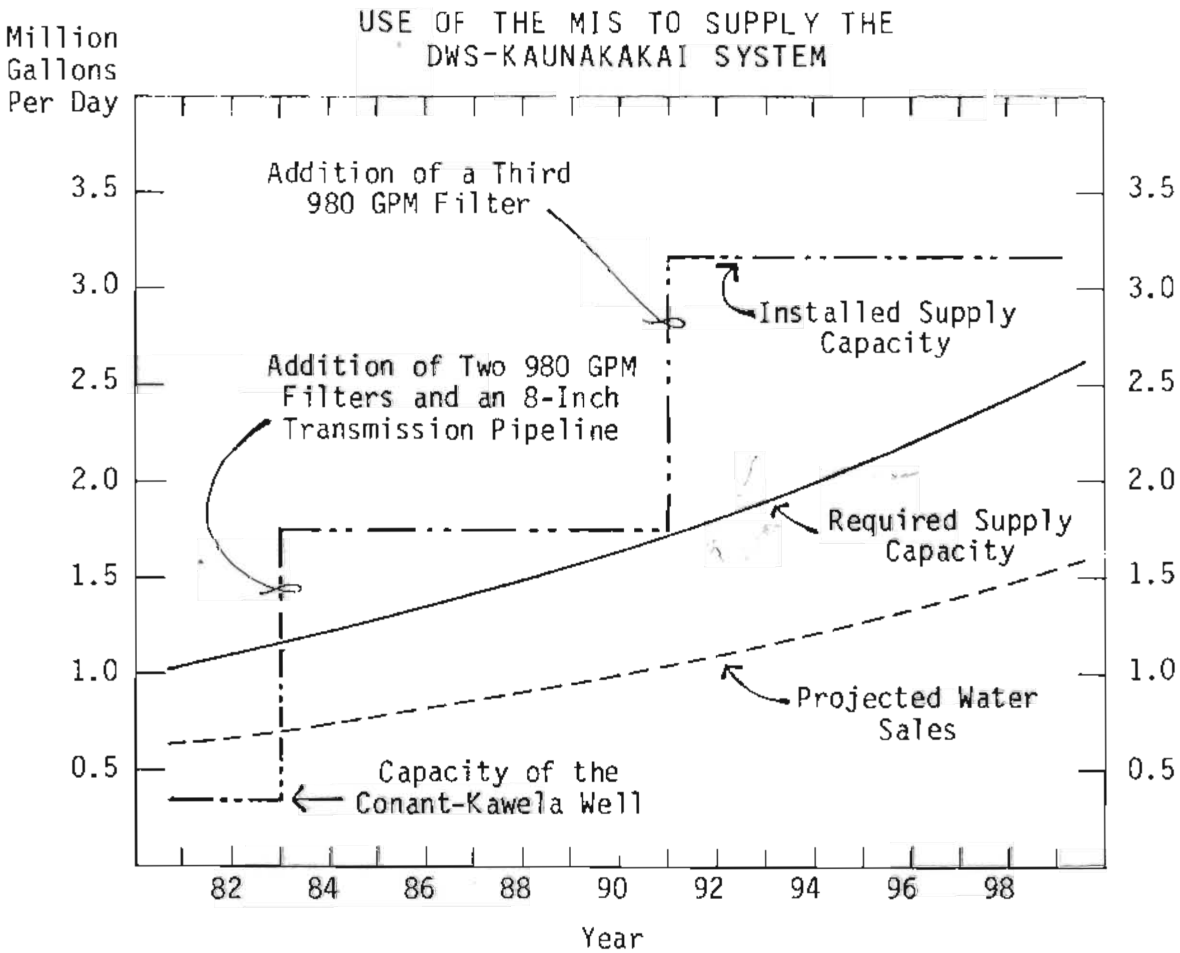


Figure 26. Supply Increments Required for the DWS-Kaunakakai Option of Continuing Use of the MIS

Flocculating Agent Injection	$ 20,000
Two 980 GPM Gravity Filters	600,000
8,300 Feet of 8-Inch Ductile Iron Pipe	375,000
Subtotal	$ 995,000
Engineering	75,000
Total	$1,070,000

2. Addition of Treatment Capacity. By 1991, a third 980 GPM filter would be required, again with one of the filters providing standby capacity. Its cost is estimated to be $330,000.

980 GPM Gravity Filter	$300,000
Engineering	30,000
Total	$330,000

3. Installation of New Waikolu Valley Wells for the MIS. The projection on Figure 27 shows that combined agricultural and DWS use would exceed the capacity of the MIS in about 1994. It is assumed that two wells would be installed, each outfitted with 1.5 MGD pumps. DWS' share of the $1,670,000 cost would be 18 percent or $300,600.

Two 18-Inch Wells 330 Feet Deep	$ 300,000
Two 1,050 GPM Well Pump, Controls and Appurtenances	900,000
1,500 Feet of 12-Inch Pipe	85,000
1,500 Feet of 8-Inch Pipe	70,000
Electric Power	200,000
Subtotal	$1,555,000
Engineering	115,000
Total	$1,670,000

Comparative operating costs of this supply option consist of (1) purchase from the MIS, (2) chemicals and treatment plant operation, and (3) the cost of the Bureau of Reclamation loan incurred by municipal use. The basis for estimating these are as follows:

1. Purchase from the MIS. DOWALD does not have a municipal water sales rate but DWS use would entail greater pumping by MIS wells than for irrigation use alone. Accordingly, the sales price is estimated here as the electrical cost of a 300-foot pumping lift plus a surcharge of 20 percent. This amounts to approximately $0.40 per thousand gallons.

2. Treatment. Flocculant injection would only be required in the rainy season, assumed here to be four months each year. Cost during its injection is $0.06 per thousand gallons; averaged out over a year, the equivalent cost is $0.02 per thousand gallons. Operation and maintenance of the filters is estimated to be $0.08 per thousand gallons.

3. Bureau of Reclamation Loan. Principle and interest payments of DOWALD's $4.514 million, 40-year loan would be pro-rated by use. Agriculture's share would be at 3-7/8 percent interest rate and domestic use at the prevailing Treasury Department rate. That rate is 9.352 percent in

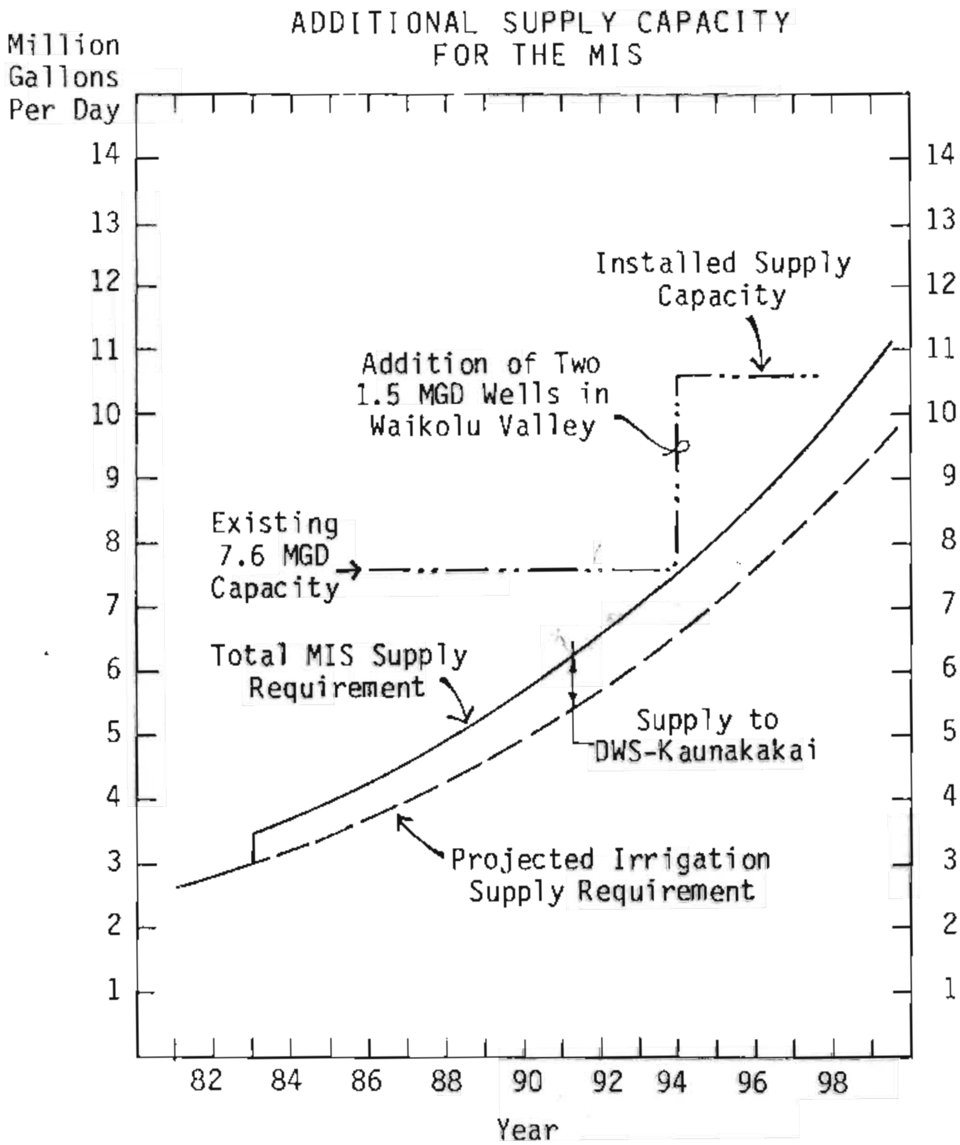


Figure 27. Supply Addition to the MIS as a Result of DWS-Kaunakakai Use

Fiscal 1982 and is expected to be 10 percent in Fiscal 1983. Using 10 percent, the annual cost of loan attributable to municipal use is shown on Table 16. It varies from $0.36 per thousand gallons initially to $0.11 in year 2000.

Option 2: Connection to the DHHL System

The evaluate connection to the DHHL system by DWS, it is assumed that the area in lower Manawainui designated for industrial use would also be supplied by DHHL. Retention of DWS' connection to the MIS would provide standby capacity, enabling combined DHHL and DWS capacity to be defined as 1.46 MGD (two DHHL well pumps of 425 and 750 GPM and the 350 GPM Conant-Kawela well pump, all operating for 16 hours). Projected supply requirements and additions to supply facilities are depicted on Figure 28. Three capital expenditure projects are envisioned to year 2000. In sequence, these would be:

1. Installation of a Pipeline to the DHHL System; Installation of a New Pump in DHHL Well 0801-01. The appropriate connection of the DHHL and DWS systems is a pipeline from just above DHHL's Kalamaula tank to DWS' 1.0 MG Kaunakakai tank. No changes in DHHL's 12-inch transmission pipeline or its storage and distribution in Kalamaula would be necessary. The inter-connecting DWS-DHHL pipeline would be 12 inches and have a total length of 12,200 feet; it would cross four drainage gulches, the largest of which is Kaunakakai Gulch.

Present combined supply capacity of 1.46 MGD would have to be expanded immediately. The most economic first addition would be replacement of the 425 GPM submersible pump in well 0801-01 with a 1,000 GPM line shaft turbine. Defined supply capacity would then be 2.0 MGD. In apportioning capital costs, all of the transmission pipeline to Kaunakakai would be borne by DWS. Given DHHL's present installed well pumping capacity in comparison to its present and future demands, replacement of the older well pump would also be entirely borne by DWS. Total cost is estimated to be $1,240,000.

12,200 Feet of 12-Inch Pipe	$ 670,000
Access Road Along Pipeline Route	80,000
1,000 GPM Well Pump, Controls and Appurtenances	350,000
Well Site Electrical	50,000
Subtotal	$1,150,000
Engineering	90,000
Total	$1,240,000

2. Installation of a Deep Well, Pump, and Related Facilities. By 1986, another well would be drilled 1,500 feet east of DHHL's existing wells. With a 1,500 GPM pump in this well, defined capacity would then be 3.46 MGD. Pro-rated costs of this investment, based on a comparison of contributed supply capacity versus required supply until the next supply increment would be undertaken in 1994, are 80 percent DWS, 20 percent Industrial Development in Manawainui, and zero for DHHL. Estimated cost of the new well and related facilities is $1,200,000.

TABLE 16. Pro-Rated Principle and Interest Payments on the Bureau of Reclamation Loan for DWS Use of the MIS

Year	Projected DWS Consumption of MIS Water (MGD)	DWS Share of Total MIS Sales (%)	Pro-Rated Principle and Interest Payments* (Dollars/Year)	Equivalent Cost Per Thousand Gallons (Dollars)
1983	0.476	13.6	62,670	0.36
1984	0.515	13.6	62,970	0.33
1985	0.556	13.7	63,430	0.31
1986	0.599	13.8	63,580	0.29
1987	0.644	13.8	63,740	0.27
1988	0.691	13.8	63,780	0.25
1989	0.740	13.8	63,610	0.24
1990	0.792	13.7	63,450	0.22
1991	0.847	13.7	63,300	0.20
1992	0.904	13.6	63,000	0.19
1993	0.965	13.6	62,690	0.18
1994	1.028	13.5	62,290	0.17
1995	1.094	13.4	61,860	0.15
1996	1.164	13.3	61,450	0.14
1997	1.237	13.2	60,890	0.13
1998	1.314	13.1	60,390	0.13
1999	1.395	13.0	59,820	0.12
2000	1.479	12.8	59,220	0.11

*Principle and interest payments are computed by:

(% DWS of MIS)($4,514,000)(crf [10%, 40 years])

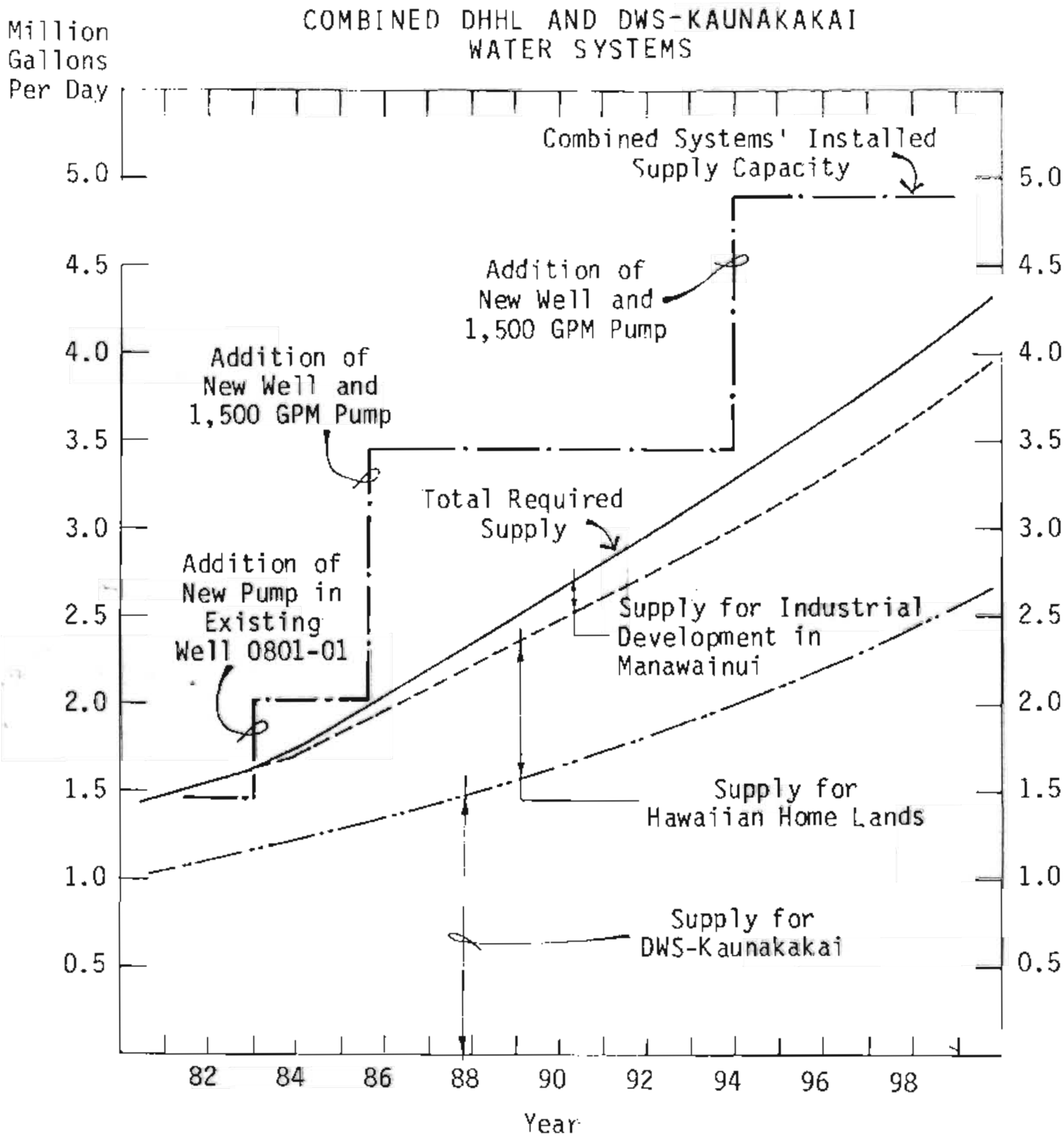


Figure 28. Supply Increments Required for a Combined DHHL and DWS-Kaunakakai System

18-Inch Well 1,100 Feet Deep	$ 500,000
1,500 GPM Well Pump, Controls and Appurtenances	400,000
1,500 Feet of 16-Inch Pipe	115,000
Electric Power	100,000
Subtotal	$1,115,000
Engineering	85,000
Total	$1,200,000

3. Installation of Deep Well, Pump, and Related Facilities. In 1994, another well and 1,500 GPM pump would be installed, this one 1,500 feet east of the well drilled in 1986. Pro-rated costs of this $1,170,000 investment, using projected requirements to year 2000 against in comparison to contributed supply, are 69 percent DWS, 12 percent Industrial Development, and 19 percent DHHL.

18-Inch Well 1,100 Feet Deep	$ 500,000
1,500 GPM Well Pump, Controls and Appurtenances	400,000
1,500 Feet of 12-Inch Pipe	85,000
Electric Power	100,000
Subtotal	$1,085,000
Engineering	85,000
Total	$1,170,000

Comparable operating costs of this option are based on filtration of Waihanau surface water as well as the electrical costs of well and booster pumping. Because of low Waihanau flows in the summer, its contribution to defined supply capacity, and the sequence of future investments is negligible. However, its rainy season flows does reduce operating time of pumps significantly. Its average year-round supply through the filters is estimated to be 0.16 MGD; filtration cost is estimated to be $0.08 per thousand gallons. DHHL's 1000-foot well pumping lift, at Molokai Electric's Schedule "P" rate, would cost between $0.73 and $0.96 per thousand gallons depending on operating hours in the billing period. Booster pumping to Kauluwai varies between $0.30 and $0.41 per thousand gallons.

Option 3: Development of New Wells Inland of Kaunakakai

Kakalahale well 0700-01 is located 1,200 feet east of DWS' that connection to the MIS. Although it is currently unused, pump tests have shown that up to 1,000 GPM at 450 mg/l chloride content is achievable. If the bottom portion of the well is sealed off, chlorides of 250 mg/l at 700 GPM may be achievable (refer to the salinity profile, Figure 29). This suggests two ways to utilize the well: (a) pump as is at 1,000 GPM and desalinize by reverse osmosis, or (b) seal the well bottom, pump at 700 GPM, and blend its water with fresher water from a new well north of Puu Luahine. Because option (a) would still require a new well by 1985, option (b) is a more economic approach and is assumed in the costs given below. The connection to the MIS would continue to provide standby capacity.

1. Development of Kakalahale and a New Well; Installation of Transmission Pipeline. A 700 GPM pump would be installed in the Kakalahale well and a 1,500 GPM pump in a new well north of Puu Luahine. With the Conant-Kawela well, defined supply capacity would be 2.45 MGD, adequate through 1997 (see Figure 30). A 12-inch transmission pipeline would also be required, bringing the total initial investment to $2,590,000.

18-Inch Well 1,100 Feet Deep	$ 500,000
1,500 GPM Well Pump, Controls and Appurtenances	400,000
1,500 Feet of 16-Inch Pipe	115,000
Electric Power	100,000
Subtotal	$1,115,000
Engineering	85,000
Total	$1,200,000

3. Installation of Deep Well, Pump, and Related Facilities. In 1994, another well and 1,500 GPM pump would be installed, this one 1,500 feet east of the well drilled in 1986. Pro-rated costs of this $1,170,000 investment, using projected requirements to year 2000 against in comparison to contributed supply, are 69 percent DWS, 12 percent Industrial Development, and 19 percent DHHL.

18-Inch Well 1,100 Feet Deep	$ 500,000
1,500 GPM Well Pump, Controls and Appurtenances	400,000
1,500 Feet of 12-Inch Pipe	85,000
Electric Power	100,000
Subtotal	$1,085,000
Engineering	85,000
Total	$1,170,000

Comparable operating cost of this supply option is the electrical energy of pumping. The 1,000 feet well pumping lift, using Molokai Electric's present Schedule "P" rate, would cost between $0.73 and $0.96 per thousand gallons depending on the hours the pump operates in the monthly billing period.

Option 3: Development of New Wells Inland of Kaunakakai

Kakalahale well 0700-01 is located 1,200 feet east of DWS' that connection to the MIS. Although it is currently unused, pump tests have shown that up to 1,000 GPM at 450 mg/l chloride content is achievable. If the bottom portion of the well is sealed off, chlorides of 250 mg/l at 700 GPM may be achievable (refer to the salinity profile, Figure 29). This suggests two ways to utilize the well: (a) pump as is at 1,000 GPM and desalinize by reverse osmosis, or (b) seal the well bottom, pump at 700 GPM, and blend its water with fresher water from a new well north of Puu Luahine. Because option (a) would still require a new well by 1985, option (b) is a more economic approach and is assumed in the costs given below. The connection to the MIS would continue to provide standby capacity.

1. Development of Kakalahale and a New Well; Installation of Transmission Pipeline. A 700 GPM pump would be installed in the Kakalahale well and a 1,500 GPM pump in a new well north of Puu Luahine. With the Conant-Kawela well, defined supply capacity would be 2.45 MGD, adequate through 1997 (see Figure 30). A 12-inch transmission pipeline would also be required, bringing the total initial investment to $2,590,000.

Kakalahale Well, No. 0700-01
Summary of Measured Water Depths and Computed
Groundwater Level Elevations

Date	Measurement By Whom	Water Depth (feet)	Computed Water Level Elevation* (feet msl)
7-13-76	USGS	976.10	5.6
10-11-76	USGS	975.94	5.8
2-09-77	USGS	976.11	5.6
4-08-77	USGS	976.14	5.6
6-02-77	USGS	976.37	5.4
9-13-77	USGS	976.30	5.4
12-13-77	USGS	976.26	5.5
4-05-78	USGS	976.37	5.4
7-12-78	USGS	976.39	5.3
10-18-78	USGS	976.43	5.3
4-05-79	USGS	976.24	5.5
7-11-79	USGS	976.41	5.3
10-19-79	USGS	976.19	5.5
4-04-80	USGS	975.75	6.0
7-11-80	USGS	975.76	6.0
10-15-80	USGS	975.72	6.0
2-03-81	USGS	975.60	6.1
4-30-81	DOWALD	975.50	6.2
5-21-81	USGS	975.85	5.9
9-01-81	USGS	975.79	5.9
4-23-82	BCA	975.60	6.1

*Water Elevations are based on a surveyed elevation of 981.72 at the steel ring at the well head. This elevation is referenced to a triangulation station near the West Portal of the Molokai Irrigation System tunnel.

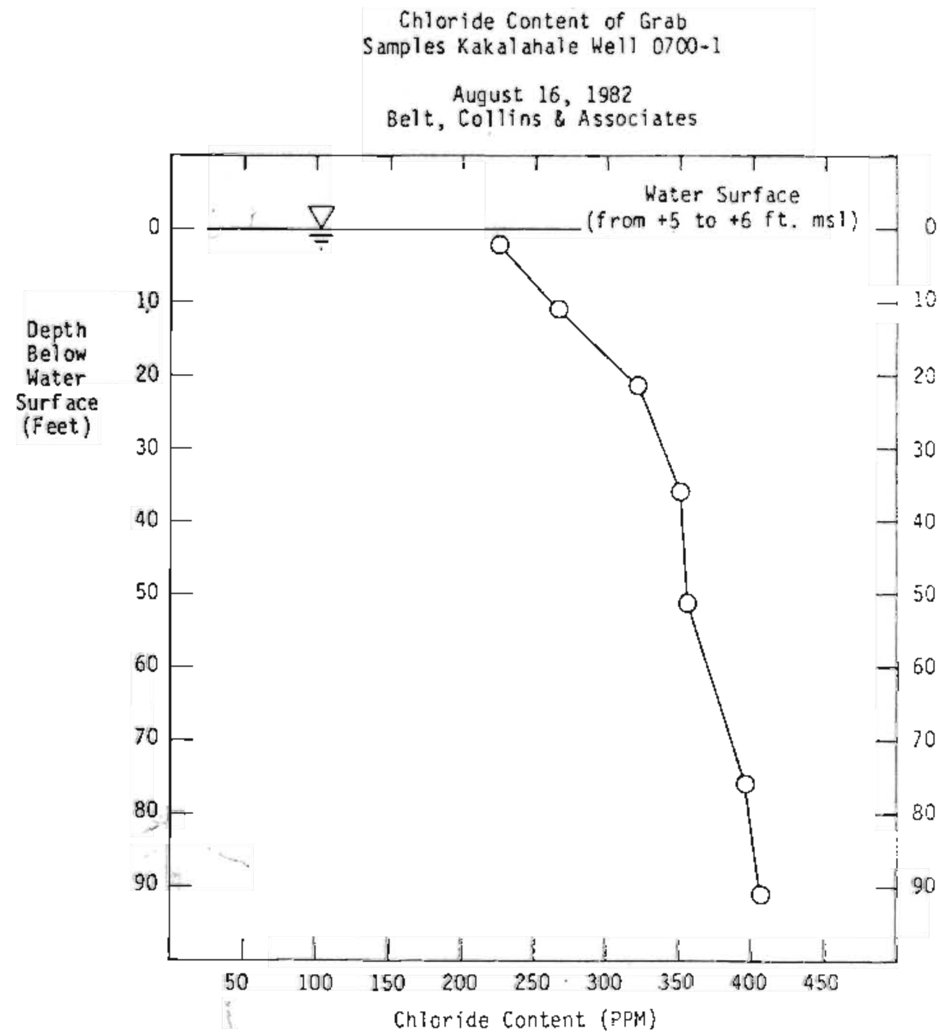


Figure 29. Water Level Measurements and Salinity Profile of Kakalahale Well 0700-01

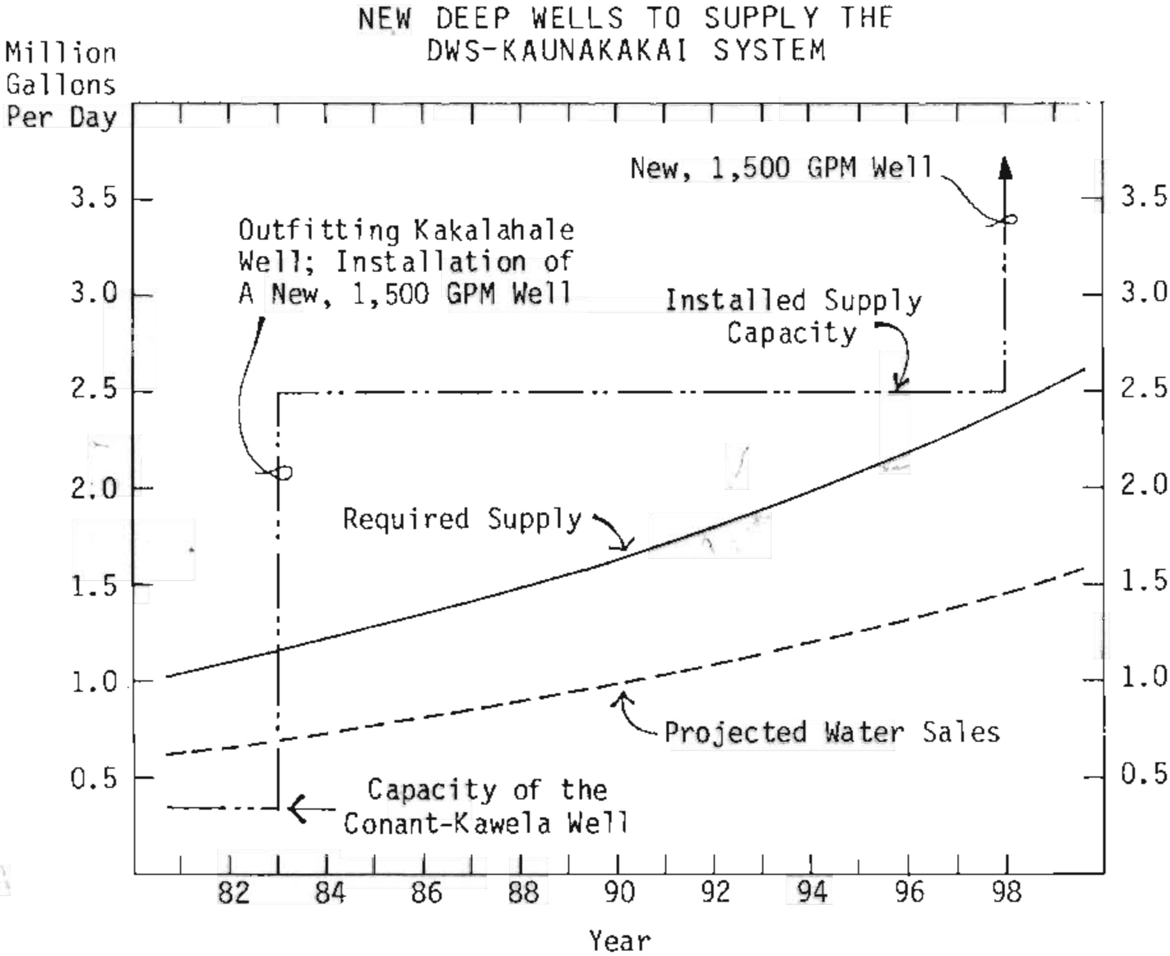


Figure 30. Supply Increments Required for the DWS-Kaunakakai Option of Developing New Wells

700 GPM Well Pump, Controls and Appurtenances	$ 325,000
18-Inch Well 1,100 Feet Deep	500,000
1,500 GPM Well Pump, Control and Appurtenances	400,000
14,800 Feet of 12-Inch Pipe	815,000
100,000-Gallon "Head" Tank	170,000
1,200 Feet of 8-Inch Pipe	50,000
Electric Power	150,000
Subtotal	$2,410,000
Engineering	180,000
Total	$2,590,000

2. Installation of a Second Well North of Puu Luahine. In 1998, another 1,500 GPM deep well would be required. Estimated cost is $1,170,000.

18-Inch Well 1,100 Feet Deep	$ 500,000
1,500 GPM Well Pump, Controls and Appurtenances	400,000
1,500 Feet of 12-Inch Pipe	85,000
Electric Power	100,000
Subtotal	$1,085,000
Engineering	85,000
Total	$1,170,000

Comparable operating costs of this option are similar to Option 2. Electric power for the 1,000-foot pumping lift would cost between $0.73 to $0.96 per thousand gallons, depending on operating time of the pumps.

Option 4: Connection to the Ualapue System

If a pipeline is installed in Kamehameha V Highway to connect the Ualapue and Kaunakakai systems, new wells would still be required immediately. Defined capacities of the Conant-Kawela and Ualapue shafts total 0.82 MGD (350 and 500 GPM pumps, each operating 16 hours a day); required supply in 1983 is 1.42 MGD (see Figure 31). An existing well on the west side of Kamalo Gulch (well 0352-05 drilled by DOWALD in 1961) was considered as a possible source. However, its progressive salinity increase at pumping rates of 400,300, and then 200 GPM during a 1962 test argue against its use.

Locations for new supply wells inland of the test well in Kamalo Gulch and in gulches east of Kamalo have been used for this evaluation. Pumpage from each is assumed to be 700 GPM. The MIS connection would be retained as standby for Kaunakakai and the second Ualapue shaft pump would be a standby in Ualapue. If well drilling and pump testing ultimately determine that pumpage of less than 700 GPM per well is necessary, then the array of capital investments described below underestimates the total cost of this option.

1. Installation of Transmission Pipeline, Booster Pumping Station and Two New Wells. An 8.57-mile long, 12-inch pipeline along the highway corridor would link the two water systems. Initially, wells in Kamalo and Wawala Gulches (at elevations 425 and 300 feet, respectively) would deliver water to

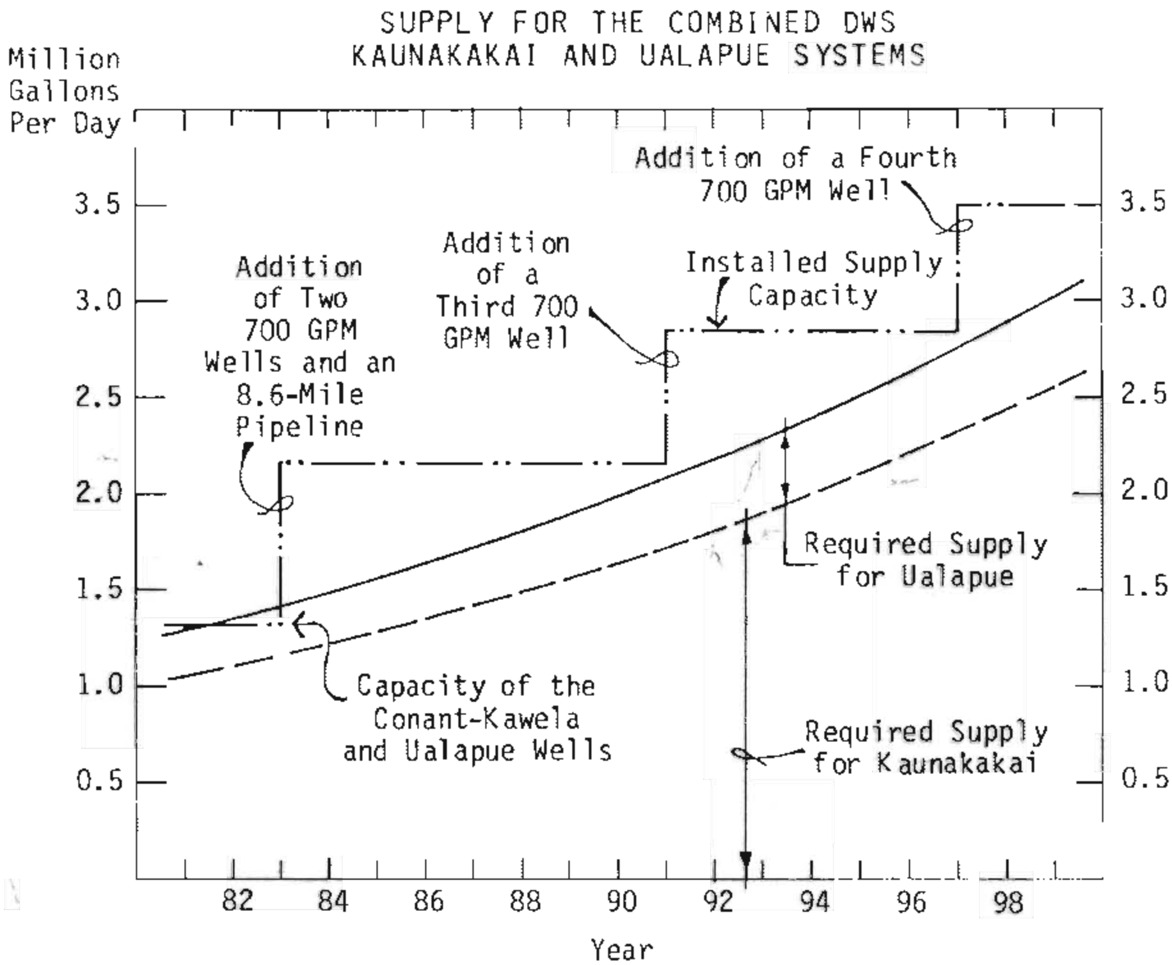


Figure 31. Supply Increments Required for a Combined Kaunakakai and Ualapue System of DWS

a 100,000-gallon head tank and booster pumping station at elevation 225 feet on the east side of Kamalo Gulch. Estimated cost of this initial capital investment is $5,475,000.

47,900 Feet of 12-Inch Pipe	$2,875,000
12-Inch Well 450 Feet Deep	180,000
12-Inch Well 330 Feet Deep	135,000
Two 700 GPM Well Pumps, Controls and Appurtenances	600,000
8,600 Feet of 8-Inch Pipe	400,000
100,000-Gallon Tank	170,000
Booster Pumping Station with Three 700 GPM Pumps	300,000
Electric Power	400,000
Access Roads to Pump Station and Wells	90,000
Subtotal	$5,150,000
Engineering	325,000
Total	$5,475,000

2. Installation of a Third Well and 700 GPM Pump. In 1991, a third well and 700 GPM pump (in Malae Gulch at elevation 400 feet) would be required. Its water would also go directly to the booster station rather than through distribution pipes of the Ualapue system. Estimated cost of this well and related facilities is $935,000.

12-Inch Well 430 Feet Deep	$ 175,000
700 GPM Pump, Controls and Appurtenances	300,000
3,800 Feet of 8-Inch Pipe	170,000
Access Road to New Well	40,000
Electric Power	155,000
Additional 700 GPM Pump at Booster Station	30,000
Subtotal	$ 870,000
Engineering	65,000
Total	$ 935,000

3. Installation of a Fourth Well and 700 GPM Pump. In 1997, a well and 700 GPM pump would be installed in Keawanui Gulch. Water from this well would reach the booster pumping station in Kamalo Gulch via the 12-inch distribution pipeline in the highway. Estimated cost of this addition is $770,000.

12-Inch Well 330 Feet Deep	$ 135,000
700 GPM Pump, Controls and Appurtenances	300,000
2,300 Feet of 8-Inch Pipe	105,000
Access Road	25,000
Electric Power	120,000
Additional 700 GPM Pump at Booster Station	30,000
Subtotal	$ 715,000
Engineering	55,000
Total	$ 770,000

Comparative operating cost of this option is electric power for pumping at the wells and booster station. The average lift of the wells is 365 feet; at Molokai Electric's current Schedule "P" rate, this cost would be $0.35 per thousand gallons. The cost energy for transmission pumping to Kaunakakai is dependent on the pumping rate. In the initial years, pumping at 700 GPM would cost about $0.10 per thousand gallons. Ultimately, pumping at 1,400 GPM would cost about 0.25 per thousand gallons.

Cost Comparison Among DWS-Kaunakakai Supply Options

The array of capital and operating costs of the four supply options described above are evaluated with the following assumptions:

- It is assumed that capital investments would be financed by 13 percent, 20-year bonds issued by the County. Annual payments would be interest only until the bonds are due. If payments included principle as well as interest, the carrying cost of capital investments would be 9 to 10 percent higher than used here.

- Operating costs assume water production 10 percent greater than projected water sales to account for leakage and miscellaneous unmetered use. All options include water production of 300,000 GPD by the Conant-Kawela well as it is the least expensive available supply. The DHHL option includes use of the Waihanau surface source equivalent to a year-round average of 0.16 MGD.

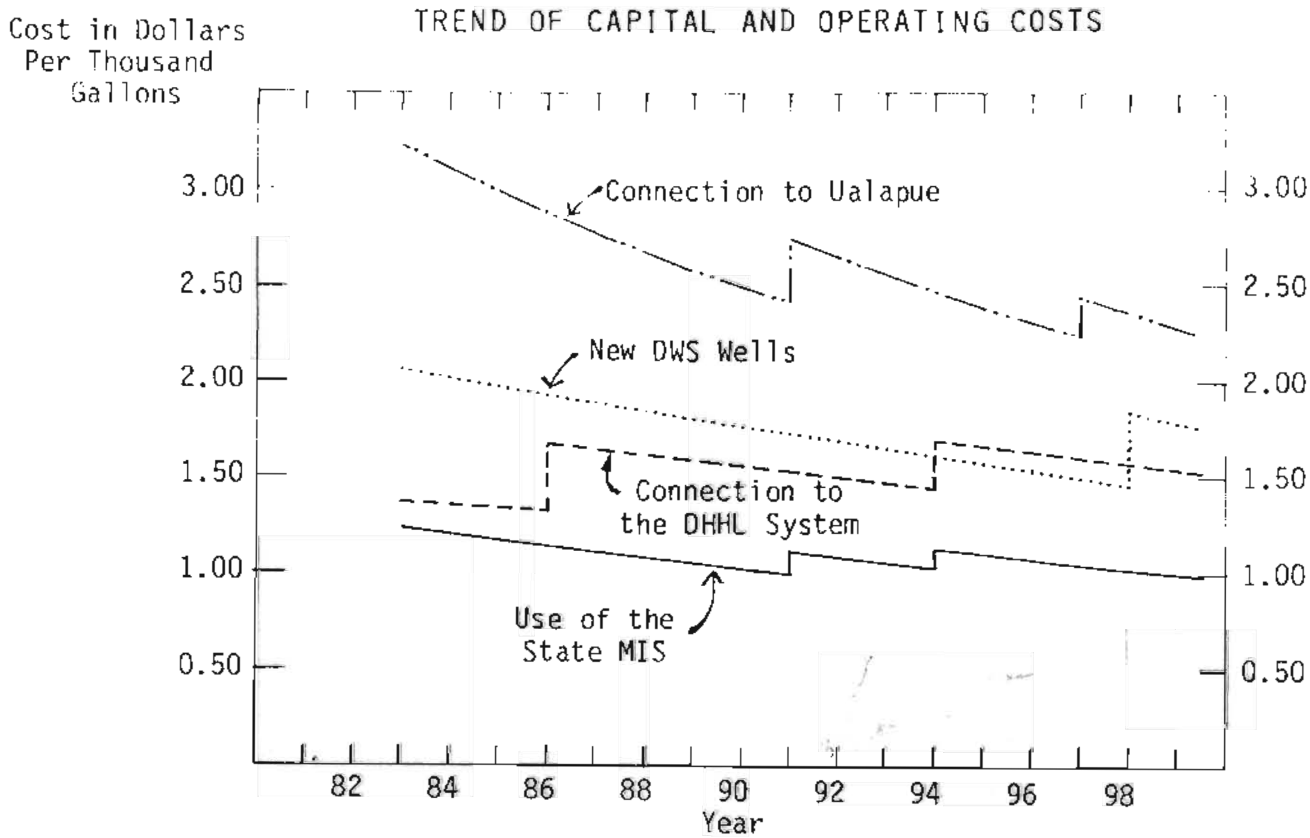
- Cost of electric power is computed from present Molokai Electric rates. These rates vary depending on pump operating time during the billing period, a factor which is reflected in figures herein.

- Initial investments for each supply option would be made in 1983. Resulting capital and operating costs are presented on an annual basis through the year 2000 rather than as a single, equivalent annual cost for the 18-year period. The variation of annual cost is as significant as its long-term equivalent.

Based on the foregoing assumptions, comparable costs of the four supply options are illustrated on Figure 32. The upper curves show that use of the State MIS has the least total cost; options using 1,000 feet deep wells, either through connection to the DHHL system or development of new wells inland of Kaunakakai, are $0.15 to $.80 per thousand gallons more costly than use of the MIS; the option of connecting to the Ualapue system is much more costly than the others due to the initial investment in the 8.6-mile long connecting pipeline.

Operating costs alone are shown on the lower curves of Figure 32. Electric power for the deep well options make them the most expensive. Substitution of diesel for electric power can reduce this significantly. Figure 33 illustrates the difference for a hypothetical 1,000 GPM, 1,000 feet lift well pump. For typical operating time (less than ten hours a day), electric power is $0.90 or more per thousand gallons whereas diesel is less than $0.50.

The influence of substituting diesel for electric power on three of the four supply option for Kaunakakai is shown on Figure 34 (for simplicity, the costly Ualapue option is not shown on this figure). No diesel substitution for the MIS is warranted, so its cost remains unchanged from Figure 32. Diesel engines would be utilized for all new well pumps in the two deep well options. In general, the cost of a diesel well pumping facility can be as



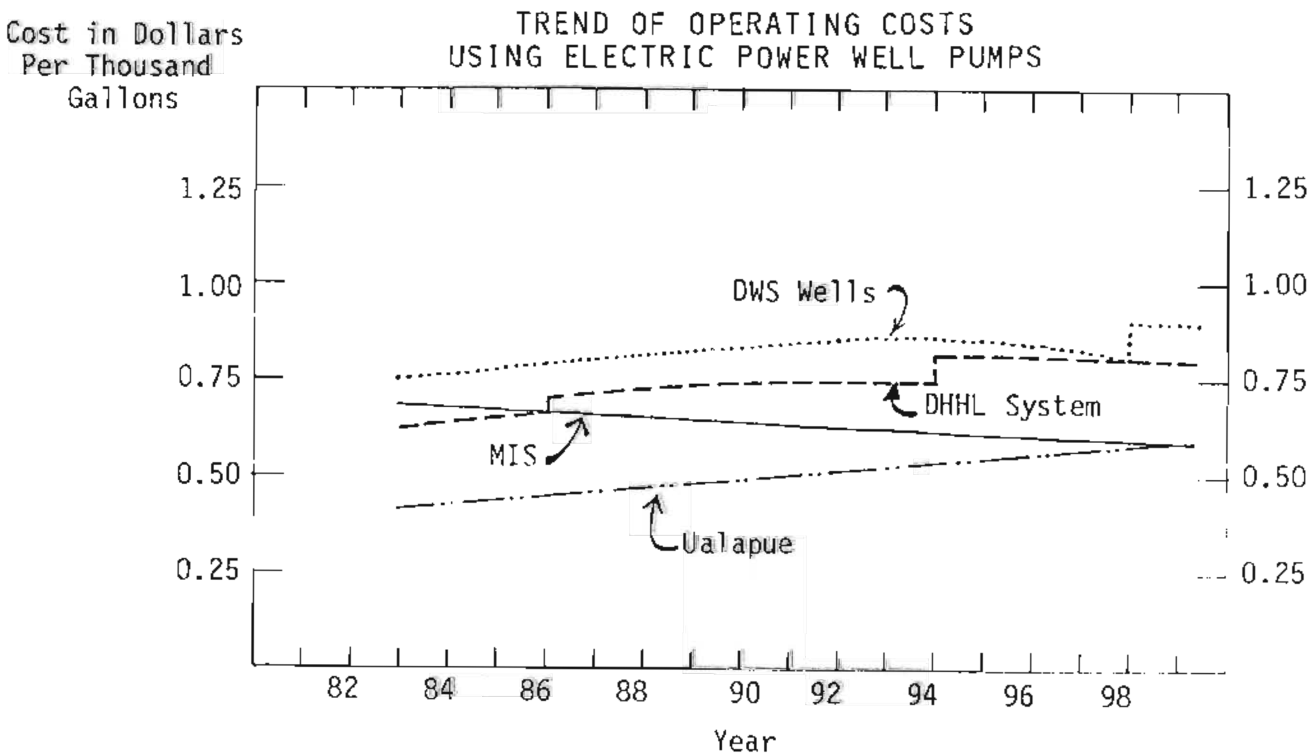


Figure 32. Cost Comparison Among Supply Options for the DWS-Kaunakakai System

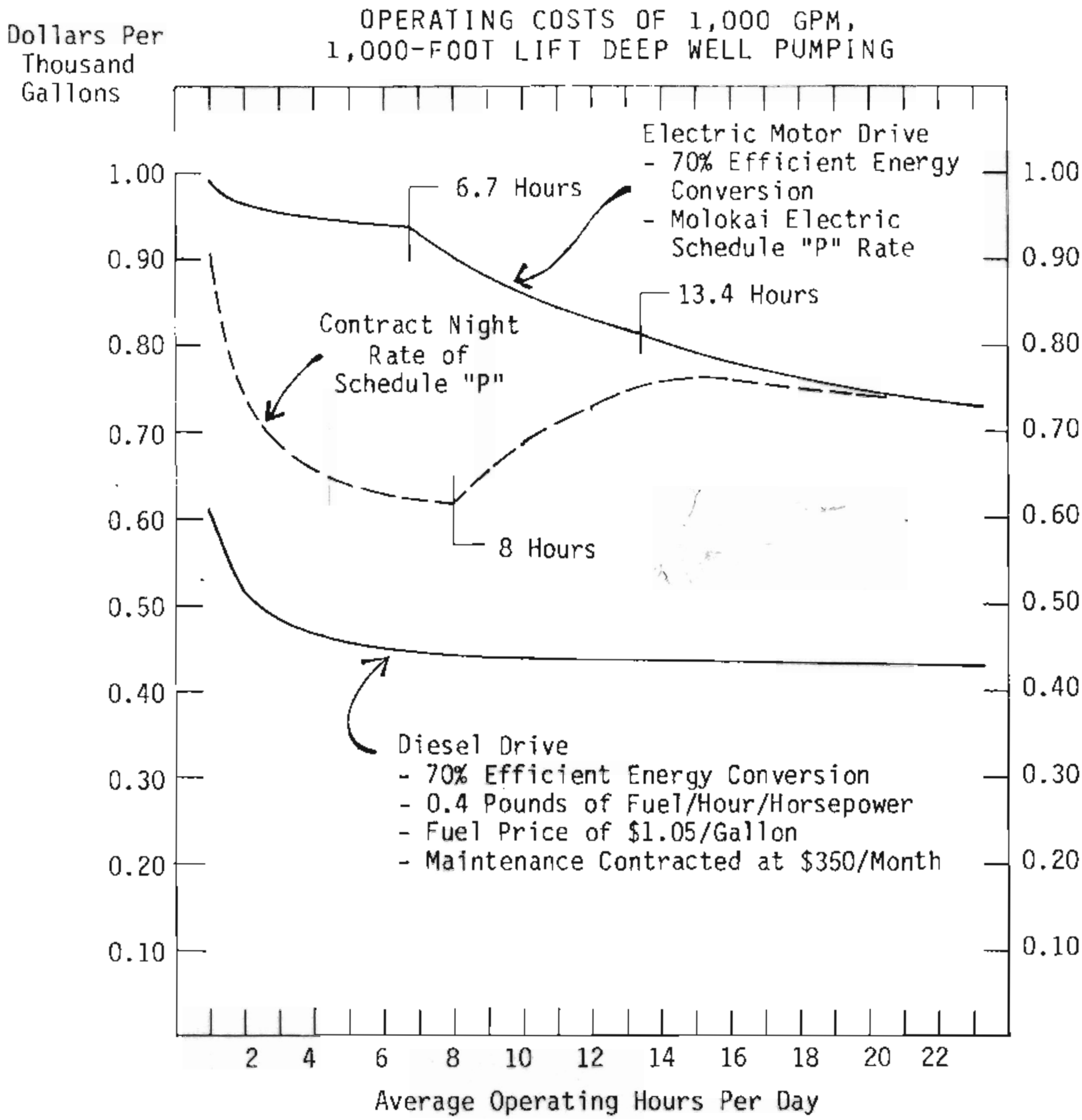


Figure 33. Comparative Costs of Diesel and Electric Power for Deep Well Pumping

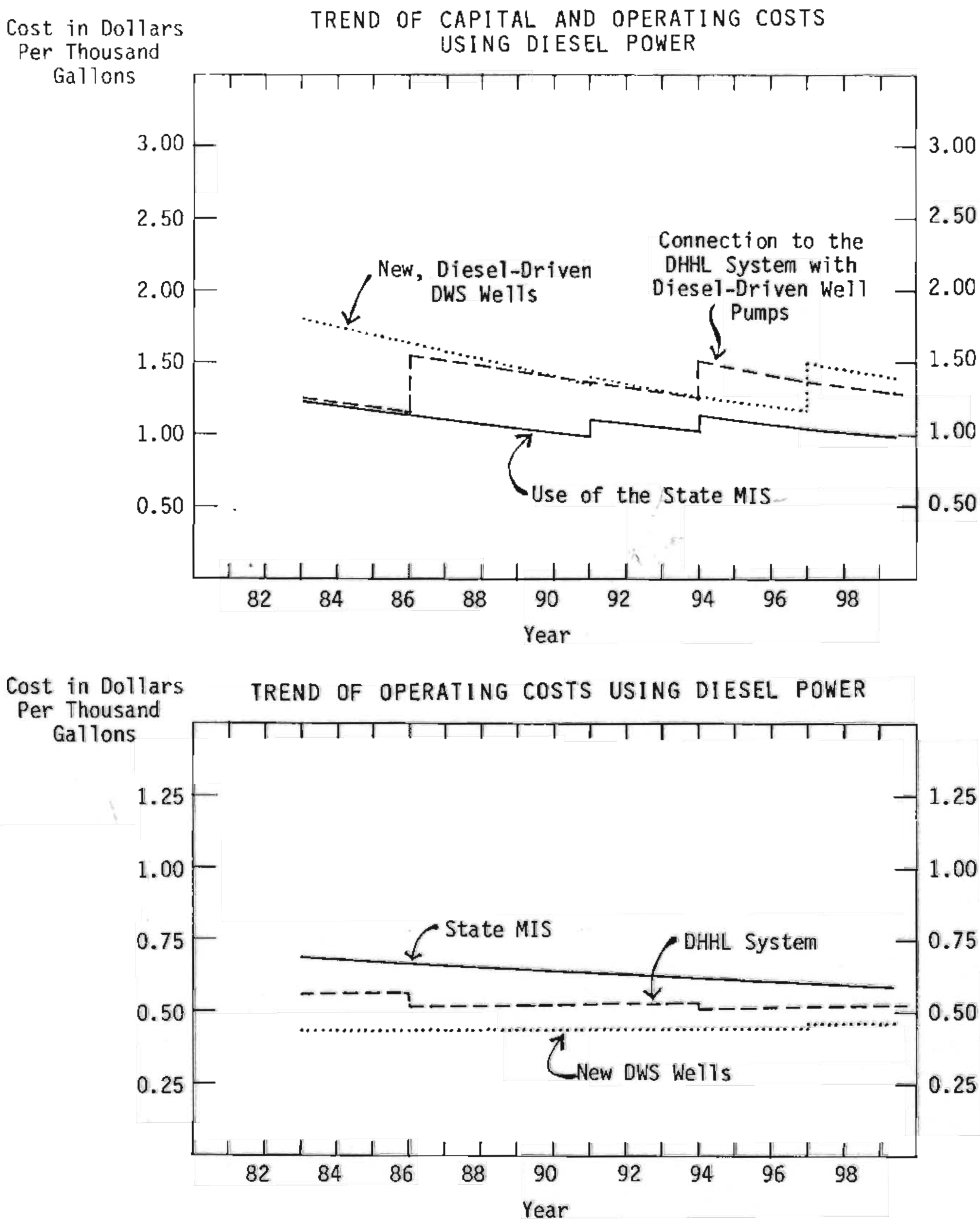


Figure 34. Cost Comparison Among DWS-Kaunakakai Supply Options Based on Diesel Drive for Deep Well Pumping

much as $100,000 higher than for electric power; maintenance and engine replacement also incur greater costs (engine replacement every eight years is assumed in the computations reflected in Figure 34). However, diesel's lower operating costs are more than offsetting. Total costs of the deep well options are closer to the cost of using the MIS and their operating costs are less.

WATER SUPPLY OPTIONS FOR WEST MOLOKAI

The occurrence of water supply shortfalls for the Kalua Koi Resort and Mauna Loa community occurs will depend on the rate of the Resort's development. Since a specific development timetable for the Resort does not exist, it is assumed for the evaluation herein that: the Resort will be fully developed by year 2000; its growth between now and then will proceed at an equal annual pace; and growth in Mauna Loa will parallel the Resort. Another key assumption in evaluating supply options is consolidation of Kalua Koi and Mauna Loa into a single system. The Molokai Ranch system does not have sufficient capacity to supply projected Mauna Loa growth; further, its quality does not meet State DOH standards and there are no plans to install the necessary treatment facilities. On the other hand, Kalua Koi's Mahana pumps and 24-inch pipeline to Puu Nana are sufficient to serve Mauna Loa as well as the Resort.

Possible supply options are limited by the lack of potable water resources within West Molokai. Three options are evaluated here, each with long transmission links to sources east of Kualapuu:

1. To expand Kalua Koi's maximum transmission through the MIS from 2 to 4 MGD; well water would continue to be added into the MIS before Kualapuu Reservoir at 10 percent more than is taken out at Mahana.

2. To purchase water from the MIS at a price which reflects both its production cost and also pay the consequences to the Bureau of Reclamation loan.

3. To install a new transmission pipeline from well sources east of Kualapuu to the Mahana pump station.

Option 1: Expand Transmission Through the MIS

Assuming the Kalua Koi's rental agreement could be renegotiated to enable daily transmission of up to 4 million gallons, the following sequence of capital investments would be required:

1. Interconnection of Mauna Loa and Kalua Koi Systems; Installation of Treatment Facilities at Mauna Loa; and Installation of an Additional Pump at Mahana. A 1,350-foot long, 6-inch pipeline from Kalua Koi's 16-inch line (below its Puu Nana reservoirs) to the 4-inch "Libby" pipeline would connect Mauna Loa to the Kalua Koi system. Treatment facilities consisting of flocculant injection into the 6-inch pipeline and automatic gravity filters at the 3 MG Mauna Loa tank would also be required. It is assumed that the MIS' Kualapuu Reservoir can provide standby capacity for this system's single source, Kalua Koi's well 0901-01 and its 1,750 GPM diesel-driven pump. However, applying standby pumping capacity criteria, a third pump at Mahana would be necessary.

1,350 Feet of 6-Inch Pipe	$ 48,000
Two 225 GPM Automatic Gravity Filters	280,000
Flocculant Agent Injection	12,000
900 GPM Pump at Mahana Pump Station	50,000
Subtotal	$ 390,000
Engineering	40,000
Total	$ 430,000

2. Installation of Second Well and Pump East of Kualapuu. In 1985, a second well and pump located 1,500 feet west of Kalua Koi's well 0901-01 would be required (see Figure 35). A pump of 1,750 GPM is recommended, probably to be diesel driven so as to match the well 0901-01 pumping facility. Assuming the MIS could continue to provide short-term standby source capacity, the two 1,750 GPM well pumps would suffice through year 2000.

18-Inch Well 1,100 Feet Deep	$ 500,000
Diesel-Driven 1,750 GPM Turbine Pump and Related Facilities	500,000
1,500 Feet of 12-Inch Pipe	85,000
Subtotal	$1,085,000
Engineering	65,000
Total	$1,150,000

3. Installation of Another Mahana Booster Pump and Participation in the Installation of a Relief Pipeline Within the MIS. In 1994, another 900 GPM pump at Mahana would be required. At about the same time, combined agriculture and domestic water use would exceed the capacity of the 24-inch distribution pipe of the MIS just below Kualapuu Reservoir. This pipeline carries all water from the reservoir down to the first branching pipeline; a parallel, 24-inch relief pipeline is recommended. Based on projected flow in the pipeline through year 2000 (peak irrigation, 70 percent; maximum daily flow to West Molokai, 30 percent), and acknowledging that the present 24-inch pipeline was installed for irrigation use, 90 percent of the cost of the relief line would be borne by domestic use on West Molokai.

900 GPM Pump at Mahana Pump Station	$ 50,000
90 Percent of 6,700 Feet of 24-Inch Pipe	725,000
Subtotal	$ 775,000
Engineering	55,000
Total	$ 830,000

Operating costs of this supply option include: (1) diesel-driven well pumps east of Kualapuu, about $0.46 per thousand gallons based on Kalua Koi's current operating costs; (2) rental of transmission through the MIS, taken to be $45,000 annually for 2 MG through 1987 and then $90,000 annually for up to 4 MGD thereafter; (3) electric power for booster pumping at Mahana, currently about $0.70 per thousand gallons for the 800-foot lift; and (4) chemicals and maintenance of treatment facilities, estimated to be $0.10 per thousand gallons.

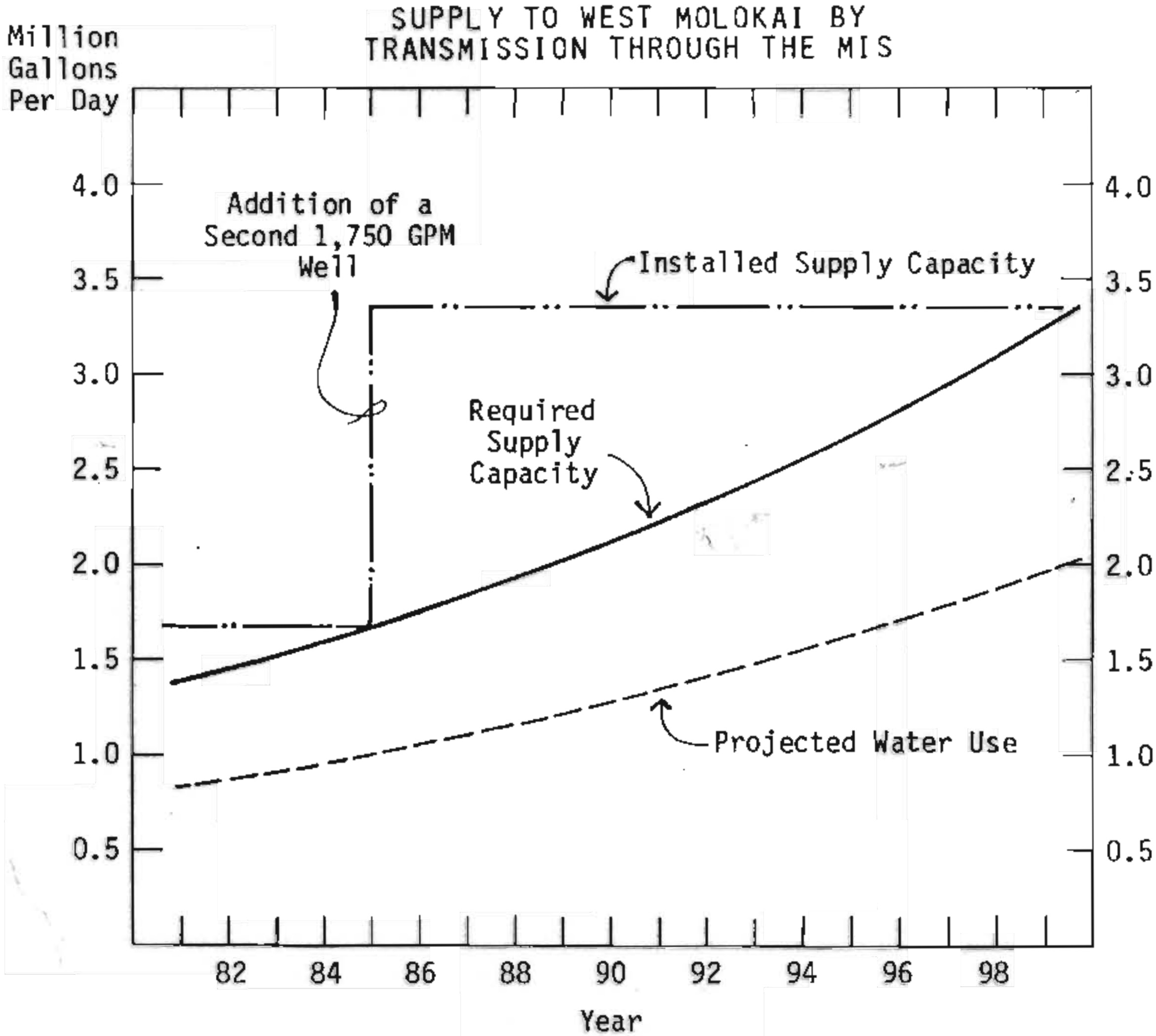


Figure 35. Supply Increments Required for the West Molokai Option of Transmission through the MIS

Option 2: Direct Purchase from the MIS

The most significant advantage to direct purchase from the MIS is use of Kualapuu Reservoir. Its storage can buffer peak seasonal use, allowing sources such as wells to be sized for lesser, year-round average use rates. In evaluating this option, the following are assumed:

1. Purchase would be at the end of the MIS distribution system. Kalua Koi's Mahana pump station and transmission pipeline would then deliver water to Mauna Loa and the Kalua Koi Resort.

2. Kalua Koi's well 0901-01 and 1,750 GPM diesel-driven pump would be incorporated into the MIS. With the pump operating up to 16 hours a day, this addition would bring total MIS supply capacity to 9.3 MGD.

3. Since use of the MIS is one of the most promising alternatives for the DWS-Kaunakakai system, it is assumed that both West Molokai and Kaunakakai are supplied by the MIS in this option. For projected water use to year 2000, irrigation supply would amount to two-thirds of the water sold; purchase by DWS-Kaunakakai, assuming continued use of its Conant-Kawela well, would be 10 to 13 percent of MIS water sales; and domestic use on West Molokai would amount to 20 to 23 percent of water sales.

4. When additions to the MIS are required, the capital cost would be shared by domestic and irrigation systems according to relative use and bearing in mind that existing facilities were built for agriculture.

5. Domestic use of the MIS will incur a pro-rated share of the principle and interest payments on the $4.5 million Bureau of Reclamation loan.

Based on these assumptions, forecast water use, and present system capacities, the following array of capital investments would be required:

1. <u>Interconnection of Mauna Loa and Kalua Koi Systems; Installation of Treatment Facilities at Mauna Loa; Addition of a Pump at Mahana.</u> Improvements required initially are identical with Option 1. A breakdown of their $430,000 cost was given previously.

2. <u>Installation of Another Mahana Booster Pump and Participation in the Installation of a Relief Pipeline within the MIS.</u> Identical with Option 1, another 900 GPM booster pump at Mahana and a 24-inch, 6,700-foot long relief pipeline within the MIS system adjacent to its Kualapuu Reservoir would be required in 1994. Ninety percent of the cost of the relief line is attributable to domestic use. The cost of these improvements, given previously for Option 1, is estimated to be $830,000.

3. <u>Installation of Waikolu Valley Wells for the MIS.</u> By 1996, forecast water use would require additional MIS source capacity (see Figure 36). Two wells in Waikolu Valley, each outfitted with 1.5 MGD pumps, are the basis for

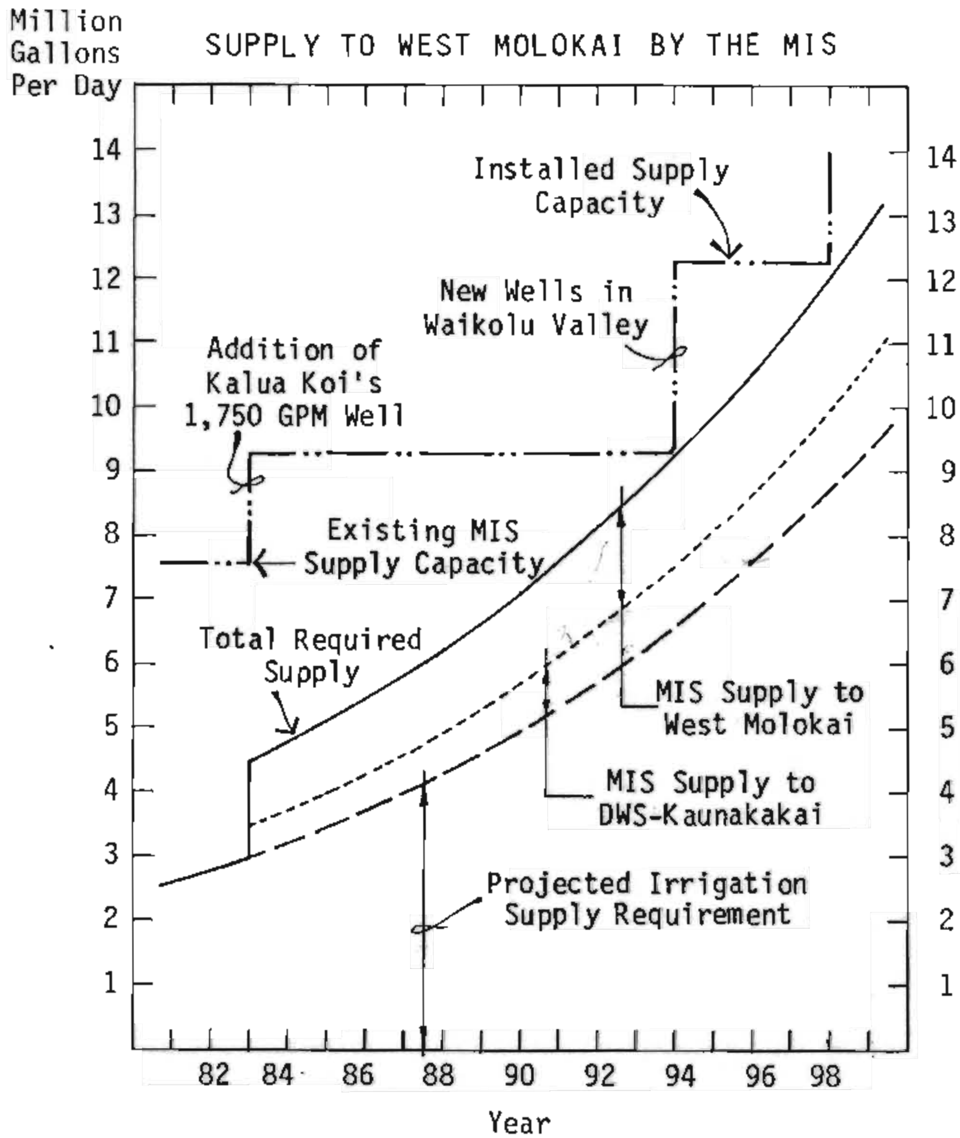


Figure 36. Supply Additions to the MIS as a Result of Domestic Use in West Molokai

the costs given below. Pro-rated shares of the $1,670,000 total are 68 percent for agriculture, 15 percent DWS-Kaunakakai; and 17 percent for municipal use in West Molokai.

Two 18-Inch Wells 330 Feet Deep	$ 300,000
Two 1,050 GPM Pumps, Controls and Related Appurtenances	900,000
1,500 Feet of 12-Inch Pipe	85,000
1,500 Feet of 8-Inch Pipe	70,000
Electric Power	200,000
Subtotal	$1,555,000
Engineering	115,000
Total	$1,670,000

Operating costs of this option include: (1) principle and interest cost of the Bureau of Reclamation loan, equivalent to $0.28 per thousand gallons for West Molokai initially and decreasing to $0.09 by year 2000 (see Table 17); (2) $0.40 per thousand gallons purchase cost from the MIS, estimated on the basis of the Waikolu Valley well pump lifts by projected pump plus an additional 20 percent; (3) booster pumping at Mahana, $0.70 per thousand gallons; and (4) operation of the treatment facilities, $0.10 per thousand gallons.

Option 3: Transmission Pipeline from Kalua Koi Wells to Mahana

If Kalua Koi's transmission contract with the State cannot be expanded beyond 2 MGD, and if direct purchase of MIS water cannot be negotiated, the solution for future transmission to West Molokai will require a new pipeline. Figure 37 shows that the new pipeline should be on-line by 1988. There are several possibilities for the new transmission link: (1) continue transmission of 2 MGD through the MIS and convey the balance through a new pipeline; (2) transmit all water to the west end via a new pipeline; or (3) add storage at both the wells and Mahana station to reduce the pipe sizes in either (1) or (2) above. Maintaining 2 MGD transmission through the MIS and providing storage at the wells and Mahana station is the most economic choice; these have been assumed in the costs given below.

1. Interconnection of Mauna Loa and Kalua Koi Systems; Installation of Treatment Facilities for Mauna Loa; and Addition of a Pump at Mahana. Immediate improvements for this option are identical with Options 1 and 2. Total estimated cost is $430,000; costs of the various elements were listed previously.

2. Second Well and Pump East of Kualapuu. In 1985, a second well located 1,500 feet west of Kalua Koi's well 0901-15 would be required. This improvement is identical to that described for Option 1. Its $1,150,000 cost includes a new well, 1,750 GPM diesel-driven pump, and related facilities.

3. Transmission Pipeline from Wells to Mahana. By 1988, transmission to West Molokai will exceed 2 MGD. With the addition of open reservoirs at the wells and at the Mahana station, a 12-inch pipe size could provide gravity transmission of sufficient capacity to Mahana well beyond year 2000. An alignment generally following the Molokai Ranch pipeline is assumed. There are two gunite-lined open reservoirs totaling 350,000 gallons storage at the

TABLE 17. Pro-Rated Principle and Interest Payments on the Bureau of Reclamation Loan for West Molokai and DWS-Kaunakakai Use of the MIS

		Domestic Use		Pro-Rated Priciple and Interest Payments		
Year	Irrigation Supply (MGD)	West Molokai (MGD)	DWS Kaunkakai (MGD)	Agriculture	West Molokai Domestic	DWS Kaunakakai
1983	3.03	1.02	0.48	118,390	103,940	48,940
1984	3.26	1.07	0.52	118,970	101,840	49,520
1985	3.49	1.12	0.56	119,480	100,000	50,030
1986	3.75	1.17	0.60	120,240	97,840	50,210
1987	4.02	1.23	0.64	120,800	96,400	50,190
1988	4.31	1.29	0.69	121,280	94,670	50,670
1989	4.63	1.35	0.74	121,950	92,730	50,860
1990	4.97	1.41	0.79	122,690	90,770	50,890
1991	5.33	1.48	0.85	123,160	89,190	51,260
1992	5.72	1.55	0.90	123,920	87,570	50,880
1993	6.14	1.63	0.96	124,490	86,190	50,790
1994	6.59	1.71	1.03	125,020	84,600	50,990
1995	7.07	1.79	1.09	125,770	83,040	50,600
1996	7.58	1.87	1.16	126,450	81,360	50,500
1997	8.14	1.96	1.24	127,050	79,780	50,510
1998	8.73	2.06	1.31	127,700	78,590	50,010
1999	9.37	2.16	1.40	128,270	77,110	50,010
2000	10.05	2.26	1.48	129,000	75,650	49,570

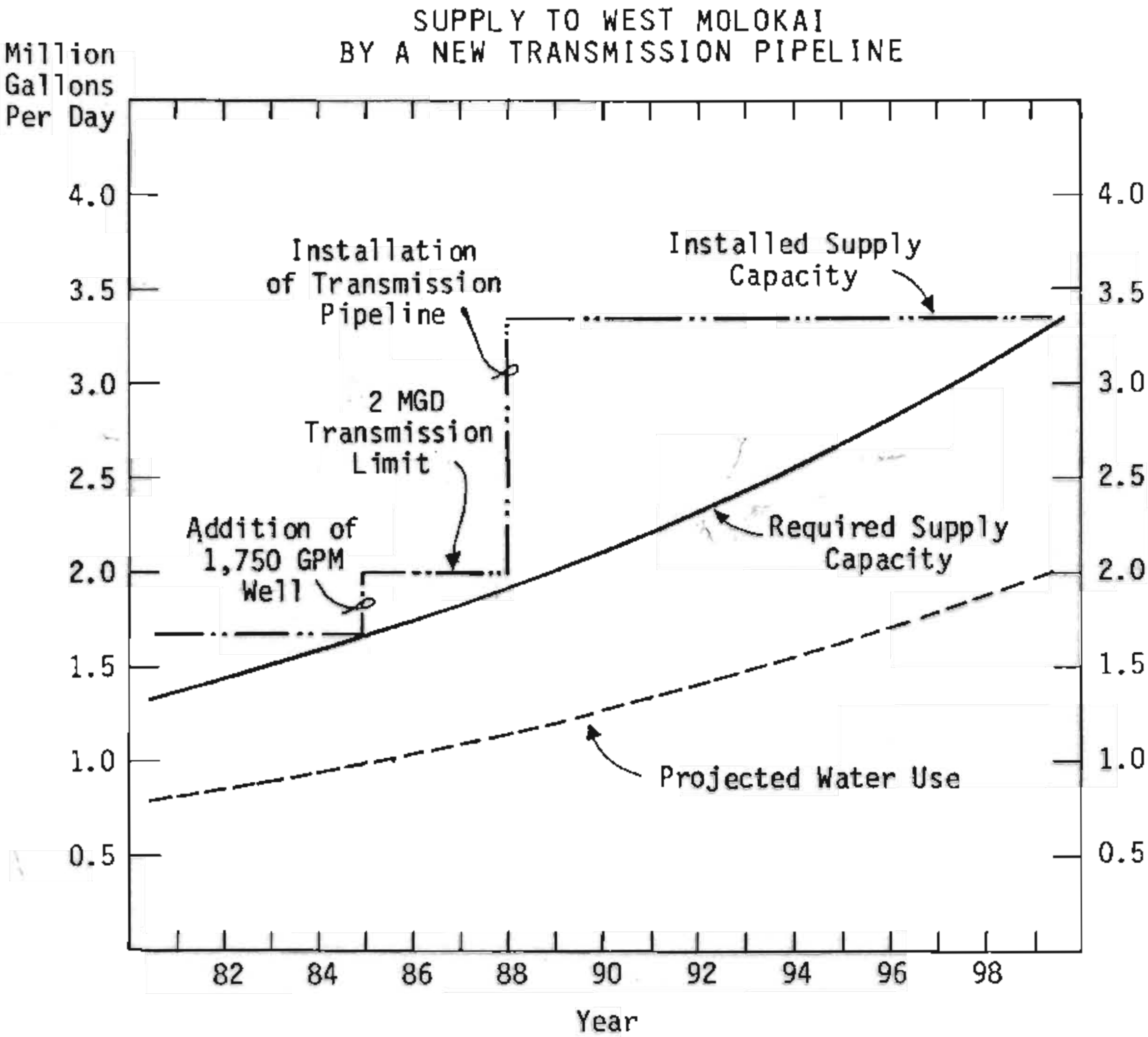


Figure 37. Supply Increments Required for the West Molokai Option of a New Transmission Pipeline

well site at present; another 650,000 gallons storage should be added. The Mahana station has no storage at present; 1,000,000 gallons storage should be installed there. Estimated cost of all improvements is $2,920,000.

40,600 Feet of 12-Inch Pipe	$2,240,000
0.65 MG Storage at Wells Site	200,000
1.0 MG Storage at Mahana Station	290,000
Subtotal	$2,730,000
Engineering	190,000
Total	$2,920,000

4. Mahana Booster Pump; Participation in Relief Pipeline Within the MIS Distribution Network. In 1994, another 900 GPM booster pump at Mahana would be required. Similar with Options 1 and 2, a 24-inch relief pipeline within the MIS pipeline network would also be required. However, domestic flow through the MIS would be about half as much as in the previous options. Accordingly, participation in the installation cost of the relief pipeline would be less.

900 GPM Pump at Mahana Pump Station	$ 50,000
50 Percent Participation in 6,700 Feet, 24-Inch Pipeline	405,000
Subtotal	$ 455,000
Engineering	45,000
Total	$ 500,000

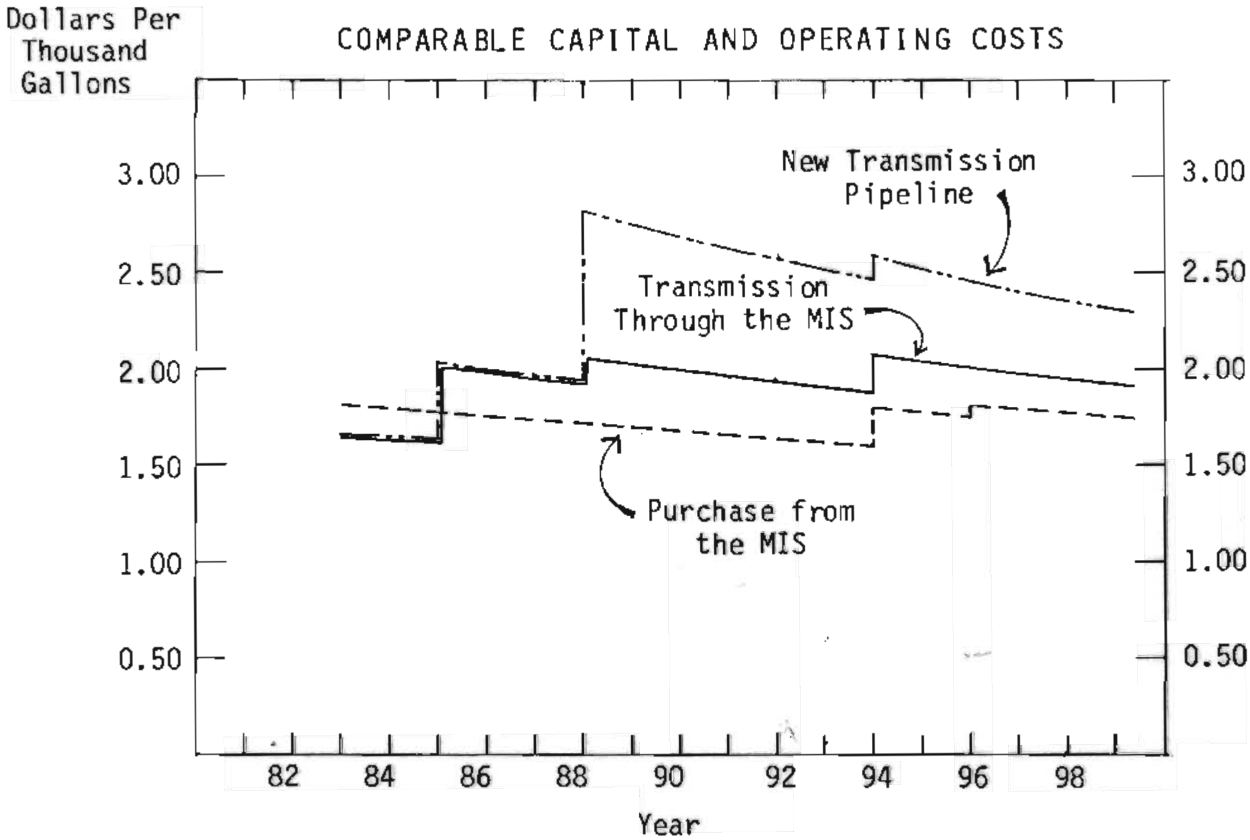
Comparative operating costs of this option include: (1) diesel-driven well pumping, approximately $0.46 per thousand gallons; (2) $45,000 annually for MIS transmission rental, equivalent to about $0.12 per thousand for the amount of water transmitted currently and $0.06 when transmission reaches 2 MGD; (3) booster pumping at Mahana, $0.70 per thousand gallons; and (4) operation of treatment facilities, $0.10 per thousand gallons.

Cost Comparison Among West Molokai Supply Options

Assuming capital investments are financed by 13 percent, 20-year bonds and supply options are initiated in 1983, comparable capital and operating costs, expressed in dollars per thousand gallons of water sold, are presented on Figure 38. The options to purchase water from the MIS or utilize its transmission capacity have approximately equivalent total costs and are significantly less than the option to install a new transmission pipeline (refer to the upper curves of Figure 38). The operating costs of all options are high and nearly equal. The unavoidable pumping lifts at supply wells and the Mahana booster station make operating costs well over $1.00 per thousand gallons.

ENERGY RECOVERY BY HYDRO-GENERATION

The cost of energy for deep well and booster pumping lifts make operating expenses of Molokai water systems high. Since dependence on pumping will be even greater in the future, ways to reduce its cost deserve investigation. One method, use of diesel engines rather than electric motors to drive deep well pumps, has already been presented (refer back to Figure 33). Another possibility is to recover energy using hydro-generators. Use of an automatic



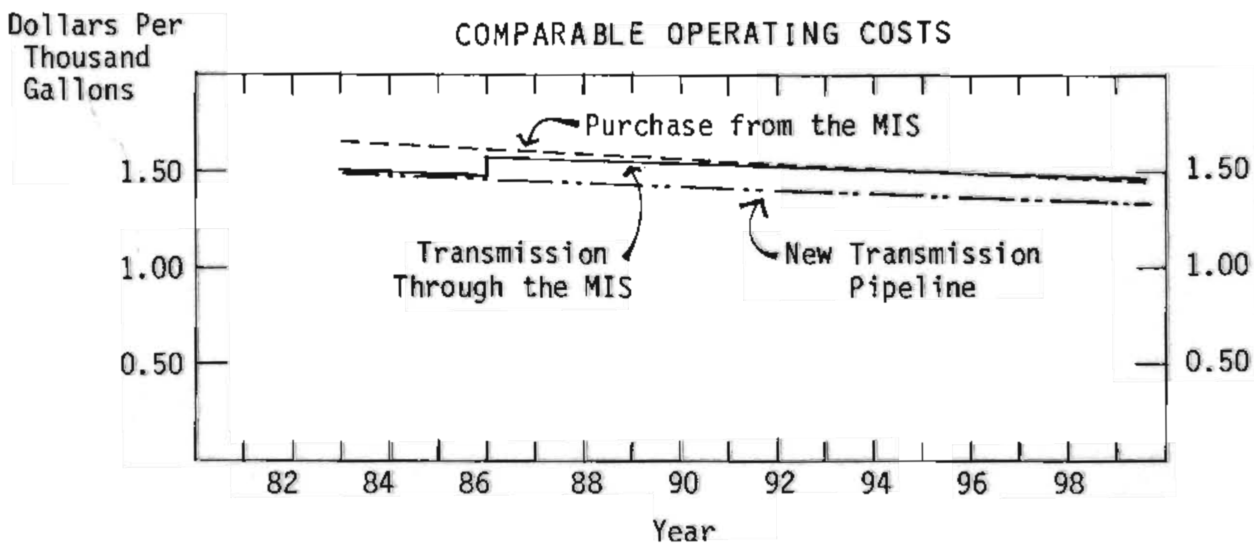


Figure 38. Cost Comparison Among Supply Options for West Molokai

control valve to govern the hydro-turbine has reduced the initial cost of such generating units; installation of such a plant in Waimea, Hawaii has recently demonstrated this. Molokai water systems have four sites of potential energy recovery.

Hydro-Generation Potential at the 1.0 MG DWS-Kaunakakai Tank

If DWS-Kaunakakai continues use of the MIS or develops its own inland wells, a hydro-generation facility located above its 1.0 MG tank would be appropriate. Figure 39 illustrates the potential energy recovery assuming installation of an 8-inch pipeline parallel to the existing 6-inch pipeline connection to the MIS. Generated energy could be sold to Molokai Electric or used to drive an on-site well pump. On-site well water would be brackish but could be blended into the domestic supply.

Table 18 summarizes an economic analysis of hydro-generation based on 350,000 GPD in the transmission pipeline, the current average flow obtained from the MIS. Greater return is achieved by direct use of generated power than through sale to Molokai Electric. At the Kaunakakai site, the extent of direct use is limited by the mixing ratio of brackish and fresh water to keep the blended water chloride content below 125 ppm. Only 20 to 40 percent of recovered energy can be used in this manner. As a result, the value of recovered energy is not quite as great as the carrying cost of the required capital investment.

Hydro-Generation Potential at the 200,000-Gallon DHHL-Kalamaula Tank

Water from DHHL wells descend 750 feet to a 200,000-gallon tank (now under construction) above Kalamaula. Figure 40 illustrates the energy recovery potential for various rates of flow in the 12-inch pipeline. The potential is expressed in two curves. The upper curve applies if water service is to Kalamaula and lower Manawainui; the lower curve applies if sufficient residual pressure to deliver water to DWS-Kaunakakai is required. Potential energy recovery is 35 to 40 percent of the energy input by DHHL well pumps.

The 75,000 GPD current water use in Kalamaula is too small to make installation of a hydro-generation facility worthwhile. If that use is substantially increased such as by supplying DWS-Kaunakakai, and if direct use of most of the recovered energy is feasible, then hydro-generation would be justifiable. A possible direct energy use would be to pump brackish water to irrigate salt tolerant crops.

Hydro-Generation Potential Within the Kalua Koi System

Water from Kalua Koi's Puu Nana reservoirs drops 400 feet to a pressure breaker near the Resort entrance and then 450 feet to its filters and 2.0 MG storage tank. Figure 41 illustrates the energy recovery potential. It amounts to between 40 and 50 percent of input energy at the Mahana pump station. Its economical recovery, however, is currently thwarted by the lack of a nearby, direct use of recovered energy and transmission distances if power is sold to Molokai Electric.

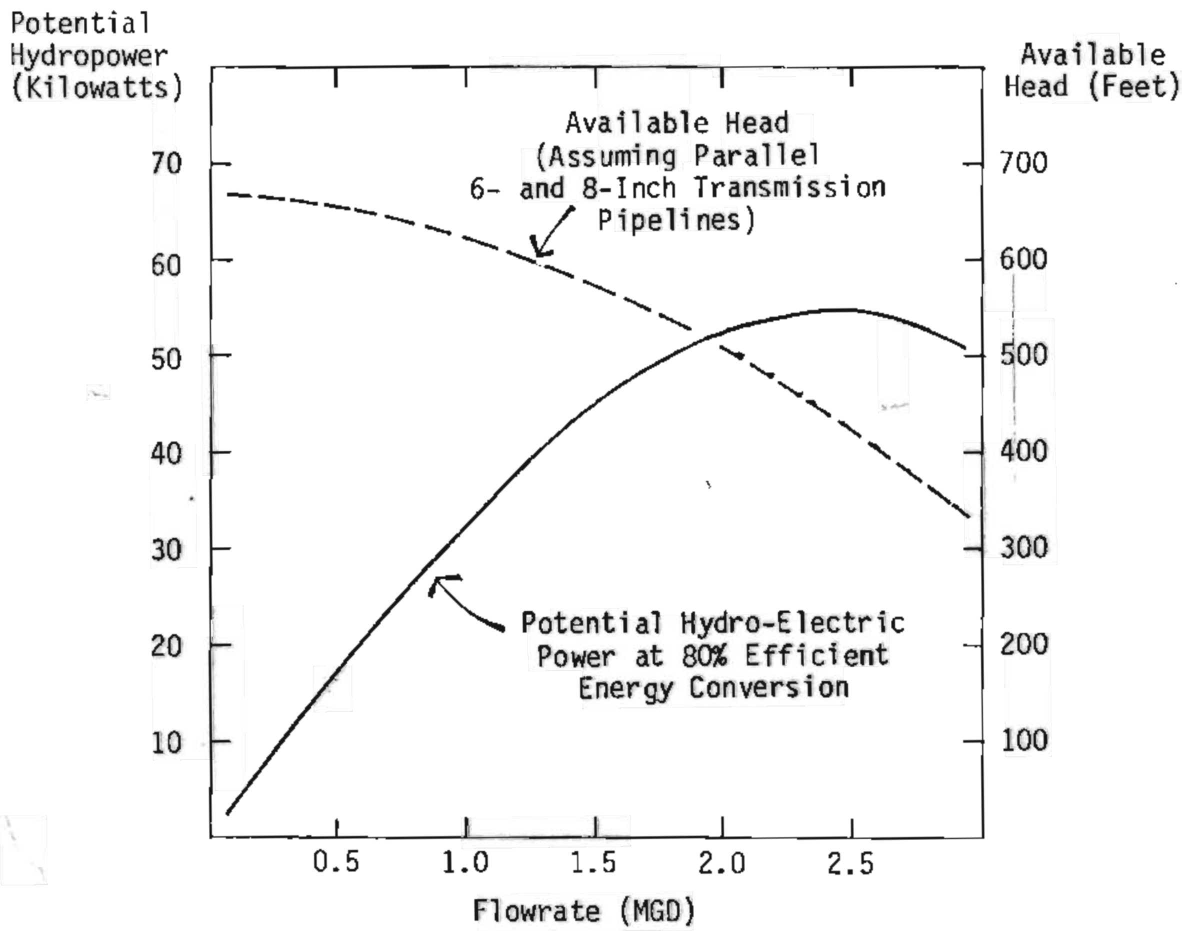


Figure 39. Potential Hydro-Electric Energy Recovery at the 1.0 MG DWS-Kaunakakai Tank

TABLE 18. Economic Evaluation of Hydro-Generation at the 1.0 MG DWS-Kaunakakai Tank

	Parameter	All Generated Energy Sold to Molokai Electric	Direct Use of Generated Energy On-Site; Excess Sold to Molokai Electric: MIS Option With Brackish Well Water Mixing	Direct Use of Generated Energy On-Site; Excess Sold to Molokai Electric: New Wells Option With Brackish Well Water Mixing
1.	Recoverable hydropower at 350,000 GPD	12.5 KW	12.5 KW	12.5 KW
2.	Amount of brackish water used for domestic mixing	none	93,300 GPD	51,300 GPD
3.	Power required for brackish well pumping	none	4.94 KW	2.71 KW
4.	Annual carrying cost of installed facilities	$11,700 to $12,800	$33,800 to $37,010	
5.	Annual value of power generation			
	(a) For brackish water produced	--	$23,160	$16,290
	(b) For power sold to Molokai Electric	$10,950	$ 6,620	$ 8,570
	(c) Total of (a) and (b)	$10,950	$29,780	$24,860

Notes on calculations made in preparing this table:

1. Recoverable hydropower is taken from Figure 39 at a flowrate of 0.35 MGD, the current rate of supply from the MIS.

2. Chloride concentrations for brackish mixing are: 25 PPM for MIS water; 70 PPM for inland wells water; and 500 PPM for brackish well water.

3. Power required for brackish well pumping includes a 275-foot lift and is 68 percent efficient.

4. Cost of a brackish well and hydro-generator facility is $260,000 (see breakdown below). Without the brackish well and pump, total cost would be $90,000.

6-Inch Well 300 Feet Deep	$115,000
70 GPM Pump, Controls, and Appurtenances	40,000
6-KW Hydro-Generator Plant	70,000
Miscellaneous Site Work	10,000
Subtotal	$235,000
Engineering	25,000
Total	$260,000

5. Carrying costs are given as a range based on 13 percent interest only bonds and 13 percent, 20-year bonds (capital recovery factor = 0.1424).

6. For the MIS option, the value of brackish water produced is avoidance of the MIS operating cost of $0.68 per thousand gallons.

7. For the inland wells option, the value of brackish water is avoidance of 1,000-foot lift, electric power well pumping, about $0.87 per thousand gallons operating nine to ten hours daily (see Figure 33).

8. Hydropower sold to Molokai Electric is worth $0.10 per kilowatt hour.

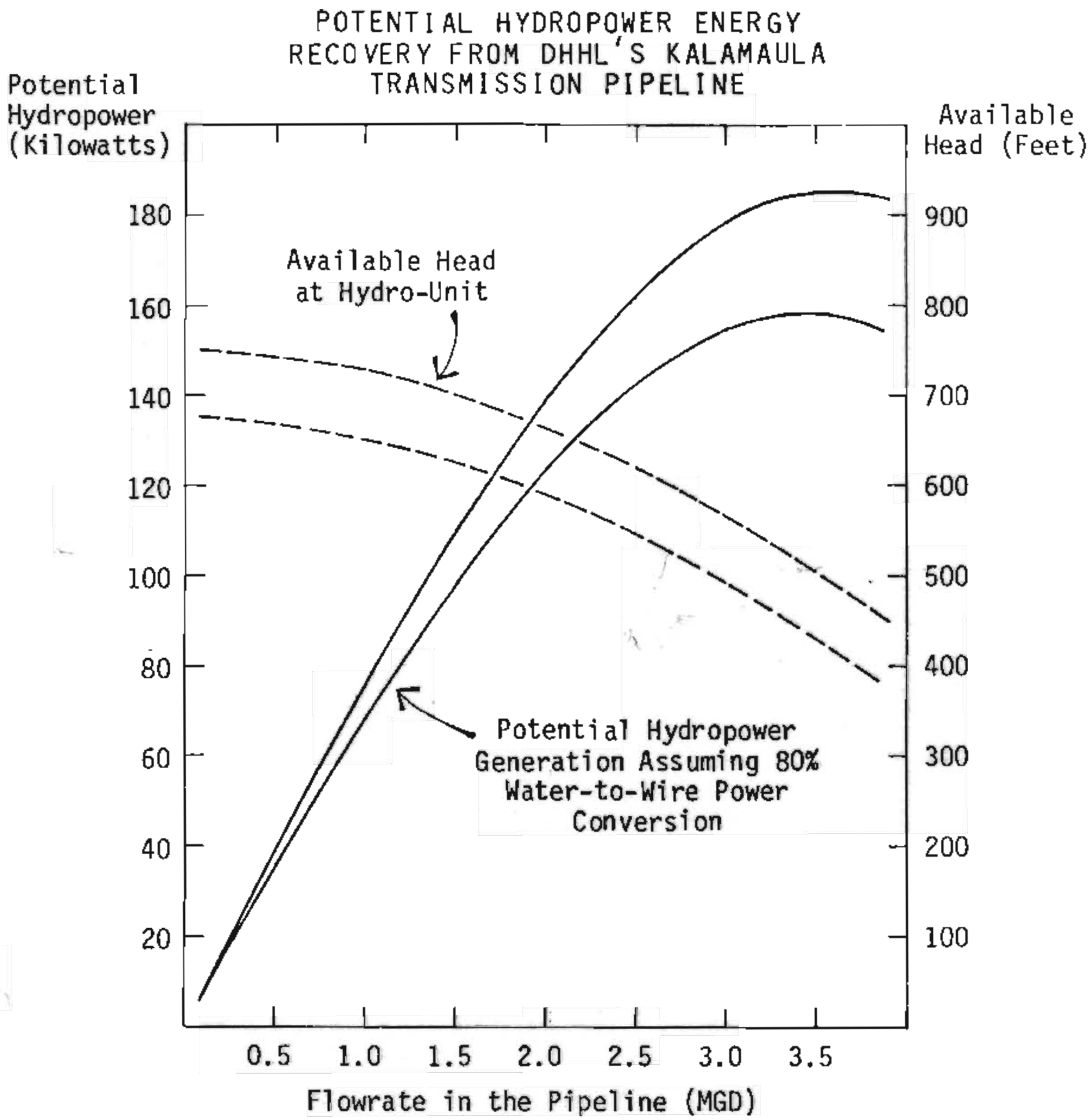


Figure 40. Potential Hydro-Electric Energy Recovery at the 0.2 MG DHHL Tank in Kalamaula

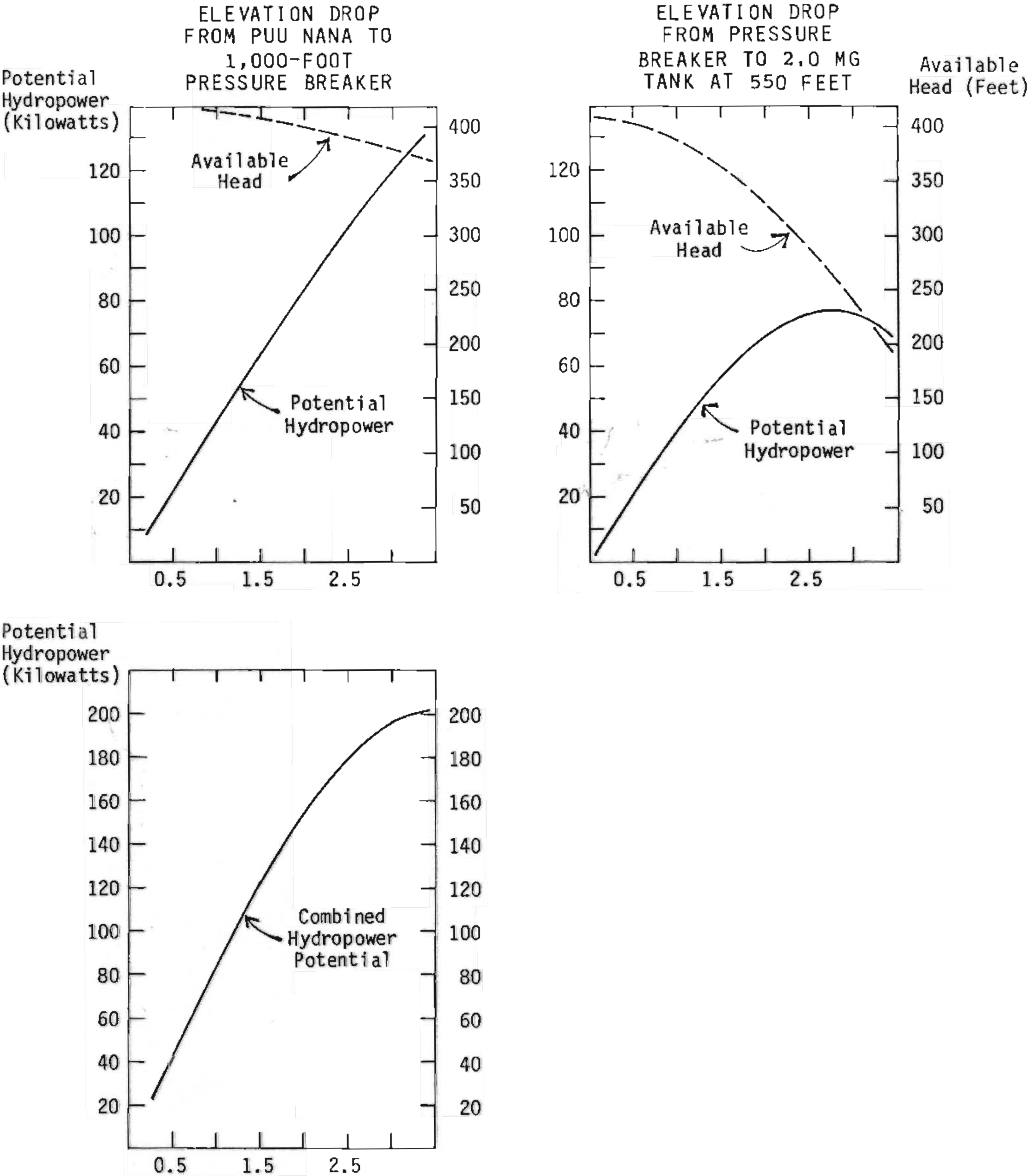


Figure 41. Potential Hydro-Electric Energy Recovery in the Kalua Koi System

CONSOLIDATION OF WATER SYSTEMS IN KALAE-KIPU

In Kalae-Kipu, water facilities of DWS, DHHL, the Federal Aviation Administration ("FAA"), and Molokai Ranch are in close proximity (see Figure 42). The DHHL system provides primary supply to the FAA and Molokai Ranch-Kipu and supplementary supply to DWS-Kalae. The redundancy of pumps and pipelines connected to DHHL's 1.0 MG Kauluwai tank suggests that economy might be achieved through consolidation:

- DWS-Kalae pumpage from the DHHL system occurs only in periods of peak use. Primary supply is from two Meyer Estate tunnels; this water is purchased at a low price and delivery to the Kalae system is by gravity. There are periods when DWS-Kalae usage is well below the supply capacity of the tunnels. In these intervals, an inexpensive source goes unused. Figure 43 and Table 19 detail the amount of unused tunnel water over the past five years.

- FAA uses a pump and hydro-pneumatic tank to deliver water to its 13 residences (only six of which are currently occupied). A connection to DWS' nearby 8-inch pipeline could eliminate the need for the pump and hydro-pneumatic tank, although a pressure reducing valve would be advisable as pressures up to 120 psi would result from DWS' 100,000-gallon tank.

- Molokai Ranch has recently installed a pump and 4-inch pipeline to supply its Kipu residences from the DHHL system. (The 3-inch pipeline from its own mountain sources is now a standby source.) Connection of Molokai Ranch's tanks to DWS' 8-inch pipeline could eliminate the need for the Ranch's pump.

If the four water systems in Kalae were operated as a single entity, the connections to eliminate redundant pumps should be considered. As separate systems, however, expanding the DWS-Kalae system service to include FAA or Molokai Ranch-Kipu in order to fully utilize Meyer tunnels water has unfavorable cost consequences. More water would have to be pumped from DHHL in periods of high use.

If the systems remain separate, DWS should install a bypass of its pump at the DHHL tank. A control valve on the bypass line, actuated by the level in DWS' 100,000-gallon tank, would enable flow from the Kalae system into DHHL's tank during periods when an excess supply from Meyer's Waikalae Tunnel is available. The rate of flow in the bypass would be restricted to the 15 to 20 GPM flowrate from the tunnel so pipes and valves would be small and relatively inexpensive. Projections of DWS-Kalae use establish that there will be periods of excess tunnel water for the next 15 years. For at least the next five years, the annual amount of excess tunnel flow into the DHHL tank should exceed the amount pumped from it during periods of peak Kalae system use (compare DWS' pumpage from DHHL in Table 20 with excess Waikalae Tunnel flow in Table 19).

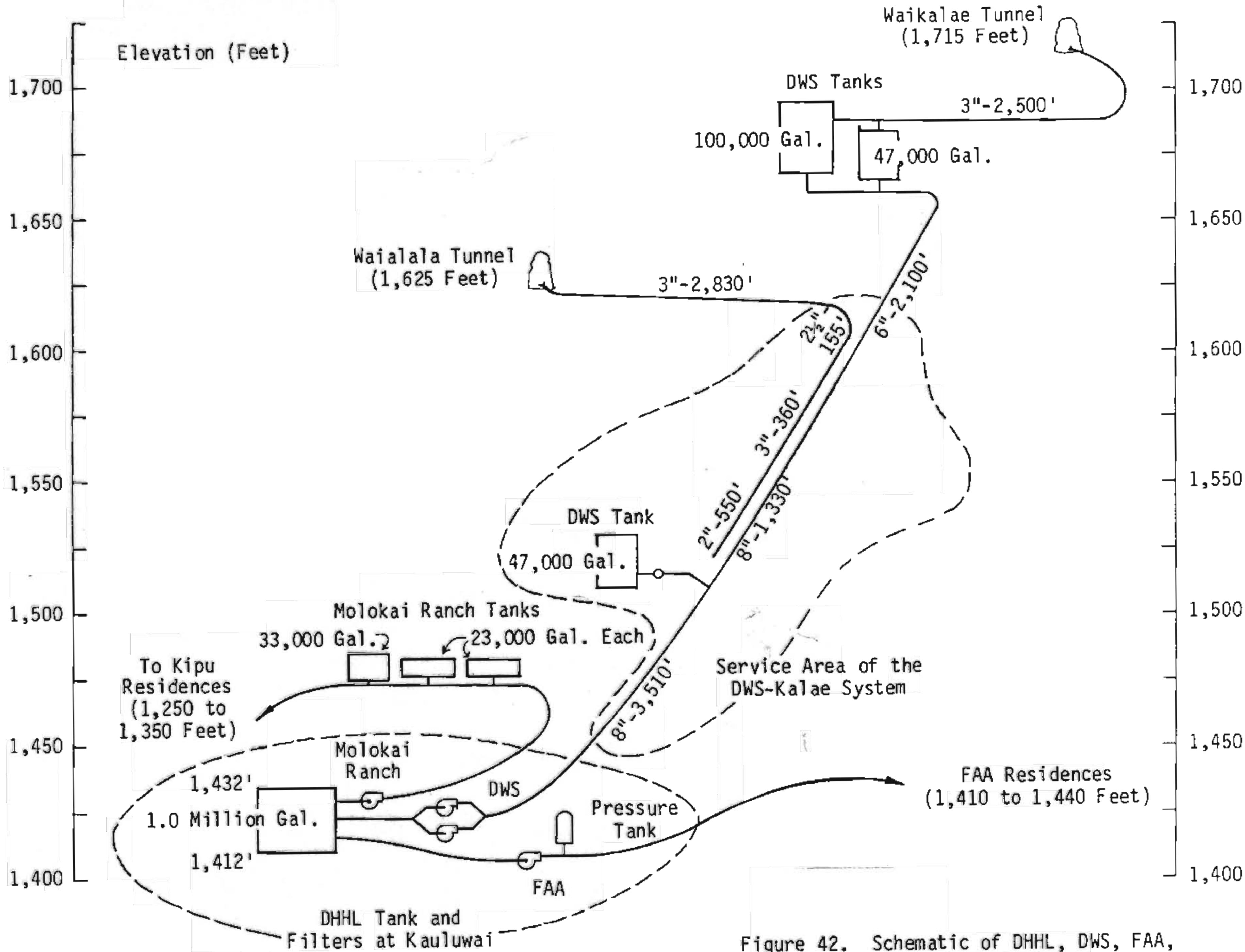


Figure 42. Schematic of DHHL, DWS, FAA, and Molokai Ranch Water Facilities in Kalae-Kipu

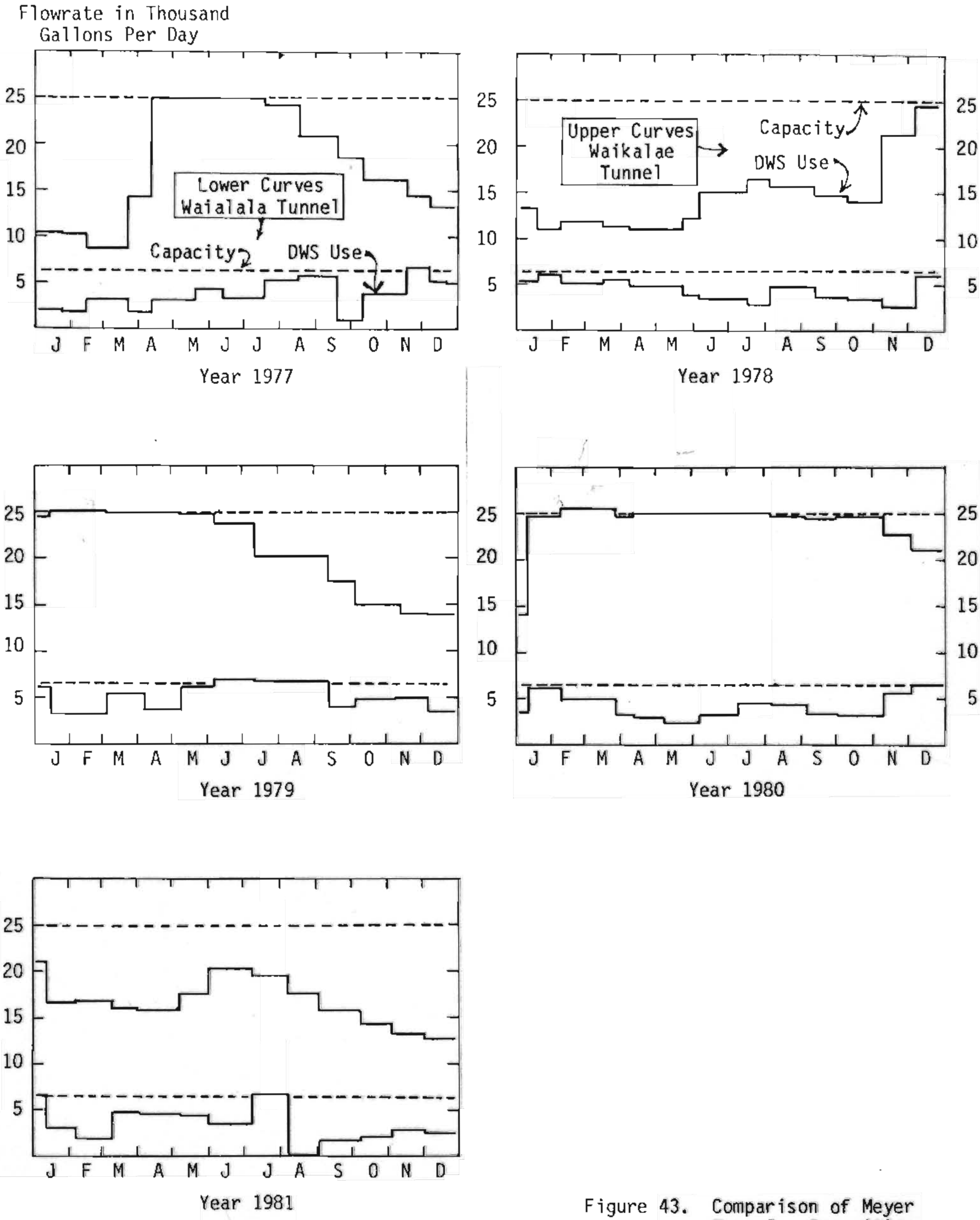


Figure 43. Comparison of Meyer Tunnel Capacities and DWS-Kalae Use

TABLE 19. Annual Amounts of Unused Meyer Tunnel Water Assuming 25,000 and 6,500 GPD Capacities of the Waikalae and Waialala Tunnels, Respectively

Year	Waikalae Tunnel		Waialala Tunnel	
	Unused Flow (Million Gallons)	Percent of Tunnel Capacity	Unused Flow (Million Gallons)	Percent of Tunnel Capacity
1977	2.46	27	0.73	31
1978	3.77	41	0.76	32
1979	1.46	16	0.54	23
1980	0.33	4	0.82	35
1981	3.08	34	0.99	42

TABLE 20. Annual Water Supply and Sales of the DWS-Kalae System for the Past Five Years

Dept. Hawaiian Home lands

Year	Water Supply (in Million Gallons)			Water Sales (in Million Gallons)	Sales as a Percent of Total Supply
	Purchase from Meyer Estate	Purchase from DHHL	Total		
1977	6.684	1.245	7.929	5.755	73
1978	8.275	0.633	8.908	6.546	73
1979	10.033	0.548	10.581	6.439	61
1980	10.376	0.533	10.909	6.380	58
1981	10.010	0.566	10.576	6.876	65

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